DEPARTMENT OF NATIONAL DEFENCE
CANADA

OPERATIONAL RESEARCH DIVISION

DIRECTORATE OF OPERATIONAL RESEARCH (JOINT & LAND)

DOR(J&L) RESEARCH NOTE RN 9812

QWG AOR SOLDIER MODELLING WORKSHOP
VOLUME I: PROCEEDINGS

BY

Lisa Willner, LFORT 3

JULY 1998

OTTAWA, CANADA

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QWG AOR SOLDIER MODELLING WORKSHOP VOLUME I: PROCEEDINGS

by

Lisa Willner, LFORT 3

Recommended by: P. Bender
LFORT

Approved by: G. Lafond
DOR(J&L)

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OTTAWA, ONTARIO

JULY 1998

ABSTRACT

Programs to enhance the capability of the dismounted soldier have been started in all the ABCA countries. Models and measures of effectiveness need to be in place to assess changes in the soldiers' capabilities due to enhancements to their clothing and equipment. A joint QWG AOR/TTCP workshop was held 27 to 31 January 1997 in Ottawa to discuss programs of work, available models, and measures of effectiveness. These proceedings contain a summary of the papers given during the workshop

RÉSUMÉ

Dans tous les pays de l'ABCA, on a commencé des programmes pour accroître la capacité du soldat démonté. Il faut que des modèles et des mesures d'efficacité soient en place pour estimer les changements attribuables aux améliorations d'équipement et de vêtements. Un atelier combiné de QWG AOR et TTCP a eu lieu du 27 au 31 janvier 1997 à Ottawa pour discuter les programmes de travail, les modèles disponibles et les mesures d'efficacité. Ce compte rendu contient un sommaire des présentations données pendant l'atelier.

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PROCEEDINGS OF THE
QWG AOR SOLDIER MODELLING WORKSHOP

INTRODUCTION

1. The uncertainty and unpredictability of future conflict has changed the emphasis in force structure to light mobile forces with versatility, adaptiveness and responsiveness. Heavy forces are lethal and survivable, but demand a large logistical effort for deployment and sustainment. The new light forces are deployable, but lack lethality and survivability. This change of emphasis along with the reality for the dismounted soldier faced with a wide range of lethal hazards has caused the ABCA and NATO countries to create programs to enhance the capability of the dismounted soldier.

2. In the past, the procurement of dismounted soldier equipment by targeting specific pieces of equipment, e.g. personal weapons, helmets, etc. led to specific performance enhancements for the soldier role, but was sub-optimal for the composite battlefield performance of the dismounted soldier. There was insufficient effort to coordinate the clothing and equipment, this coordination being essential for a fully integrated and modular system for the dismounted soldier.

3. The fundamental functions of a fighting soldier on the battlefield are: to see, hear, communicate, fire, survive and move. Five distinct capability areas need to be improved to allow the soldier to complete the combat mission and perform his assigned tasks: lethality, command and control, survivability, sustainability and mobility. The goal of the Canadian Integrated Protective Clothing and Equipment (IPCE) program, like the goals of the other NATO soldier enhancement programs, is to coordinate and integrate a modular combat system offering significant capability enhancements in the five NATO capability areas of lethality, command and control, survivability, sustainability and mobility.

4. Advances in the five NATO capability areas have arisen from improvements in various technologies such as advances in munitions, sensors, communications, and information processing capabilities, improved protection to various threats as well as improved vision and navigation devices. In order to assess the improvements brought about by the new technologies, it is necessary to have models, which are able to capture the relevant parts of the soldier's battlefield. It is also necessary to have the measures defined that will allow the proper assessments to be made.

BACKGROUND TO WORKSHOP

5. At the QWG AOR meeting held in the UK in July 1995, Dr. D. Oxenham suggested that TTCP WTP 6 and QWG AOR become involved in joint studies and workshops. At that meeting it was agreed to hold a joint workshop on two soldier combat models, Close Action Environment (CAEN) from the UK and Integrated Unit Simulation System (IUSS) from the US, and their application to advanced soldier system programs. These were the only two developed computer models representing the individual soldier in sufficient detail to be useful in current soldier modernization programs. The US HOD, Mr. Walter Hollis, advised that he would produce a draft plan of action to integrate the work of TTCP and QWG AOR. The workshop was scheduled for March 1996. Unfortunately, not all the required participants were available in the desired time frame, and the workshop was cancelled. Then TTCP WTP-6 was temporarily disbanded.

6. In July 1996, at the meeting of the 22 QWG AOR held in the UK, Mr. Hollis of the US suggested that a workshop be held under the combined auspices of QWG AOR and TTCP for the exchange of information on CAEN and IUSS. In August 1996, Mr Hollis attended a bilateral OR Symposium held in Ottawa where he suggested that the workshop be pursued under the auspices of QWG AOR. This new workshop would focus on modelling the soldier, and in particular, measures of effectiveness, rather than an explicit comparison of CAEN and IUSS. It was agreed that Canada would take the lead in setting up the workshop and extend an invitation to QWG AOR members. The QWG AOR meeting was to be held 5-11 February 1997 in Ottawa, so it was decided to hold the workshop in Ottawa as well, having it take place 27-31 January 1997.

7. At a TTCP Technical Liaison Group (TLG) -8 (Soldier System Modernization) meeting held in Toronto, in June 1996, Australia and the UK agreed to investigate the possibility of organizing a workshop aimed at developing a set of measures of effectiveness

which would be acceptable to all nations. The measures of effectiveness would be used to evaluate the changes in effectiveness of dismounted soldiers as a result of changes in their clothing and equipment. As a step towards co-operation in this area, TLG-8 agreed to co-sponsor the workshop in January. An invitation to the workshop was therefore also extended to TLG-8 members.

8. As NATO Panel III WG-4 is also working on soldier modelling, invitations were sent to TTCP TLG-8 members, TTCP WTP-6 points of contact, QWG AOR points of contact, and some NATO Panel III WG-4 members. Papers were elicited from scientists from the UK, US, Australia, New Zealand, Canada (including scientists from DCIEM, DREV and DRES) and the Netherlands known to be working in the area of soldier system analysis. Participants at the workshop also included several contractors. A list of participants is contained in Annex A.

WORKSHOP OBJECTIVES

9. The objectives of the workshop were:

   a. to exchange information on national efforts on soldier system modelling;

   b. to agree on a set of common measures of effectiveness;

   c. to determine areas of possible collaboration and propose a way ahead; and

   d. to provide input to the QWG AOR meeting the following week.

APPROACH

10. The first two days of the workshop were set aside for presentations. Canada, Australia and the Netherlands gave their presentations on the first day. The UK and the US made their presentations on the second day. The New Zealand presentation and one extra Canadian presentation were made Wednesday morning. The rest of Wednesday and Thursday were reserved for discussions. On each of these two days, the group was divided into three syndicates as shown on the agenda in Annex B. Participants chose their own groups with the restriction that delegates from each country should split themselves up among the syndicates. At the end of each of the two days of discussion, the syndicates made presentations on what

they had discussed. Friday was reserved for general discussion including agreement on a way ahead, on a set of common definitions, and direction for the proposals to be made to QWG AOR. A summary of the discussions and results arising from the workshop can be found in Research Note 9812, QWG AOR Soldier Modelling Workshop Volume II: Discussions.

PAPERS

Canadian

11. Canadian papers were presented by LCol Levesque (Director Land Requirements-5), Lisa Willner, Daniel Bourget from DREV, and Dr Scott Duncan from DRES. LCol Levesque's paper (found in Annex C) summarized the Canadian Soldier Modernization Program, covering aspects of the IPCE Capital and Technology Demonstrator Projects as well as summarizing work done under the TCCCS Radio and PDALF Project, the ERYX Anti Tank Missile Project, the Soldier's Helmet Project, the Clothe the Soldier Project, the Rifle Grenade Launcher Project, the Improved Fragmentation Vest Project and the LFCS Project. Daniel Bourget discussed the generation of personnel vulnerability data for combat models. He covered the types of data that can be produced by current models, models (Timberwolf, ComputerMan, CASPER, CASRED, blast models and ORCA), the types of inputs that these models need and the effect of body armour. Slides from his presentation are found in Annex D. Dr. Scott Duncan gave two presentations (Annexes E and F). The first was on Materials/Thermal Strain and Body Region Hazard Assessment Models at DRES. The second was on Modelling the Thermal Response to NBC Protective Clothing. Lisa Willner then gave a presentation on Wargaming and Analysis in Support of IPCE Projects, including some preliminary thoughts on appropriate measures of effectiveness (Annex G).

Dutch

12. Dr. Maarten Manders from the Netherlands gave an overview of the Dutch soldier modernization program as well as the set-up and program of work at TNO (Annex I).

Australian

13. Mr. John Coleby started with an overview of the DSTO organization. He then talked about Project Wundurra (the Australian soldier modernization project) including some of the problems for soldiers peculiar to Australia. He provided an overview of some of the related

research activity at DSTO, including some of the field study analysis and a summary of the set of measures they were using for their analysis (measures of capability, outcome, effectiveness and performance). Slides for Mr. Coleby's presentation are found in Annex H.

British

14. Michael Wright gave a presentation on work that has been done in the UK on modelling the soldier from a Human Factors point of view (The Soldier Day). The presentation included a discussion of performance shaping factors, data collection and how the human factors data might be input into operational analysis. He also talked about the UK models EXPERT and IPME. Slides from his presentation can be found in Annex J. Alan Moss presented the FIST program. (See Annex K.) Ian Mitchell talked about operational analysis in support of the FIST program, and in particular, the types of scenarios used in CAEN. Slides from his presentation are found in Annex L. Examples of FIST scenarios can be found in Appendix 1 to Annex L. Peter Dooley did a presentation on measures of effectiveness from a British perspective. (See Annex M.)

American

15. Dale Malabarba started off by discussing how simulation can support soldier modernization programs. He then talked about the range of models used in the US, current directions in modelling, some definitions of measures (performance, effectiveness, and combat worth), and possible areas of international cooperation (Annex N). Matthew Rosenblatt considered dismounted infantry requirements and types of models available, and then made a comparison of CAEN and IUSS. (See Annex O.) Robert O'Brien gave an overview of Land Warrior and Force XXI Land Warrior (Annex P). He also made a presentation on Soldier Station (Annex Q). Included in this Annex is a draft set of measures of performance for Force XXI Land Warrior. John O'Keefe provided an overview of IUSS, Micro Resolution Terrain Processor (MRTP), Soldier Protective Ensemble Computer Aided Design (SPE-CAD) system, as well as some of the difficulties involved in terrain databases. (See Annex R.) John O'Keefe also gave a presentation on CASTFOREM (Annex S) and on JANUS (Annex T) for John Galloway. George Mastroianni presented an overview of the work that went into the development and validation of the dismounted movement module in IUSS (Annex U).

New Zealand

16. Col Jeff Bright and Andrew Finnie gave an overview of the New Zealand program. (See Annex V.)

DISCUSSIONS ARISING FROM PRESENTATIONS

17. Some useful comments came from discussions arising from the formal presentations. A discussion of ballistic protection from the modelling and testing points of view suggested that both models and tests give unrealistic protection levels. Models tend to assume that terrain protects limbs more that it does, and testing of material characteristics are done with clamped material, whereas hung fabrics in general give a lower V50. There was also a discussion of incapacitation criteria. The criteria are clearly dependent on the scenario, e.g. 30 second assault versus a 12 hour defence.

18. The problems of testing new equipment in trials were also discussed. Comparison of current equipment with proposed equipment may be complicated by the following two items: the difference in the ability to make full use of equipment due to differences between new users of proposed equipment and experienced users of current equipment; and the variation between an extension of current capability and a new capability arising from new equipment. Synergism effects are also difficult to model. For example, the Australians found that night vision enhances the ability to see at night, but the platoon still moves in a compact group; the introduction of a personal radio allowed a more day-like operation.

ADDITIONAL INFORMATION PROVIDED

19. Before everybody left, points of contact were given for each country. These points of contact are listed in Annex W. John O'Keefe provided a set of useful World Wide Web addresses and a bibliography of American papers. This information is found in Annex X. The Americans also gave out two papers that they thought would be of interest to all the participants. These papers are found in Annexes Y and Z. John O'Keefe provided a list of data requirements, which are found in Annex AA. The British gave out maps with the locations of all the DERA establishments. (See Annex BB.)

CONCLUSIONS

20. These papers provide an overview of the work being done in the various countries as well as some initial thoughts on appropriate measures for analysis. They led directly into the workshop discussions and way ahead, which are found in RN 9812, QWG AOR Soldier Modelling Workshop Volume II: Discussions.

21. Out of both the papers and the discussions came the following two conclusions:

a. The problem of soldier system analysis is both an important one and a difficult one. The available models are limited in what they can do, and the analysis of the soldier and his clothing and equipment as a system is complex because of the human elements involved.

b. Collaborative effort in this area is useful, because all the countries are working on similar issues, and there is so much to do.

ANNEX A
DOR(J&L) RN 9812
July 1998

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AGENDA FOR SOLDIER MODELLING WORKSHOP

27-31 JANUARY 1997

Monday January 27 1997

845	Administration Brief and Address by Chair	Ms. L. Willner
900	Welcome	Mr. G. Lafond
915	Canadian Soldier Modernization Program	LCol J.H.J. Levesque
945	Ballistic Protection Models and Generation of Personnel Vulnerability Data	Mr. D. Bourget
1030	Coffee	
1100	Materials/ Physiology & Body Region Hazard Assessment Models at DRES	Dr. S. Duncan
Lunch		
1300	Wargaming and Analysis in Support of the Integrated Protective Clothing and Equipment Projects	Ms. L. Willner
1345	Australian Presentation	Mr. J. Coleby
1500	Coffee	
1530	Dutch Presentation	Dr. M.P.I. Manders

Tuesday January 28 1997

845	British Presentations	Mr. A. Moss Mr. I. Mitchell
1015	Coffee	
1045	British Presentations	Mr. P. Dooley Mr. M. Wright
Lunch		
1300	American Presentations	Mr. D. Malabarba Dr. G. Mastroianni Mr. R. O'Brien
1500	Coffee	
1530	American Presentations	Mr. J. O'Keefe Mr. M. Rosenblatt

Wednesday and Thursday 29 and 30 January 1997

845	Syndicate Sessions
1015	Coffee
1045	Syndicate Sessions Resume
Lunch	
1345	Presentation
1430	Presentation

1515 Coffee
1545 Presentation
1630 Open Discussion

Wednesday 29 January 1997

1900 Hosted Dinner at National Arts Centre Le Café Restaurant
Soup of the Day
Grain-fed Chicken with Herb Bread Stuffing and Dried Cranberry Sauce
Screech Cake
Coffee or Tea
Glass of Wine

Friday 31 January 1997

845 Summary of Discussions
The Way Ahead - QWG AOR
Collaboration with TTCP TLG-8
Agreement of Actions

Syndicate Sessions

There will be 3 parallel syndicate sessions on Wednesday and Thursday.

Chairs for the 6 syndicates are:

1. Dr. A. Dunlop
2. Mr. D. Malabarba
3. Col J. Bright
4. Dr. G. Mastroianni
5. Mr. A. Moss
6. Mr. J. Coleby

Each syndicate will have a computer with Word, WordPerfect, Powerpoint and Harvard Graphics as well as a flip chart.

It is recommended that each syndicate choose a facilitator to write down what is being discussed on the flip chart, as well as a notetaker to summarize the discussion on the laptop to produce the presentation for the afternoon.

It is expected that delegates from each country spread themselves among the 3 syndicates each day.

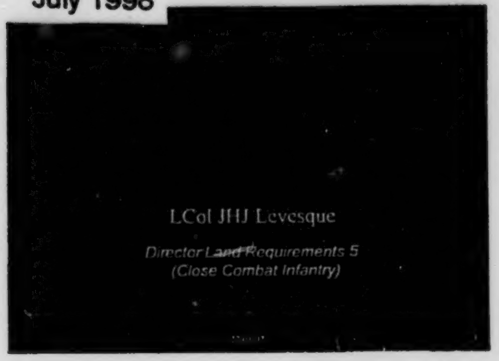
Topics for Wednesday are:

What are appropriate measures of effectiveness, measures of performance and measures of outcome for soldier modelling?
What are appropriate models and other analytical tools?
What scenarios are appropriate?
What terrains should be considered?
What constitutes a reasonable threat?
What are problem areas to model/ analyse? How might they be tackled?

Topics for the Thursday are:

What are the data requirements?
What human performance data are available, and what are needed?
What human factors data are available, and what are needed?
What do we need to find out from field trials?
How can we collaborate in data collection?
What data can we exchange?

FUTURE SOLDIER SYSTEM
by LCol JHJ Levesque, DLR 5


LCol JHJ Levesque

Director Land Requirements 5
(Close Combat Infantry)

Good Morning,

I am LCol Jacques Levesque from the Directorate of Land Requirements at National Defence Headquarters in Ottawa.

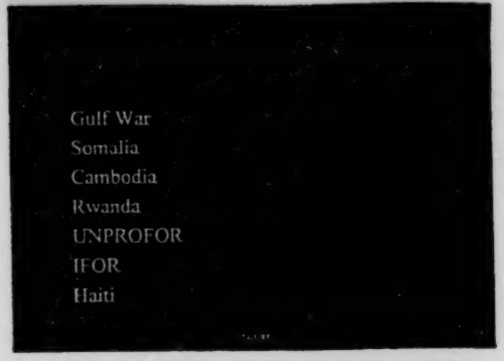
Compte tenu de l'auditoire international, je vais faire ma presentation dans la langue de Shakespeare, mais je serai pret a repondre a vos questides dans la langue de Moliere a la fin de mon expose si vous le desirez.

The future soldier system is an important subject, the occasion is timely and of most importance is the drawing together of friends and allies. In these times of diminishing defence budgets, cooperation and collaboration is surely the key to maintaining our readiness.

Let me first introduce the key stakeholders in DND projects which have a related operational research aspect:

PD IPCE-TD - LCol John Dick
PD IPCE - Maj Mike Bodner

OK, now lets start by looking at where we are today.


- Gulf War
- Somalia
- Cambodia
- Rwanda
- UNPROFOR
- IFOR
- Haiti

The role of the infantry in Canada is to close with and destroy the enemy. Far from diminishing in the post-Cold war era, we are now facing different challenges.

Conflict has shifted to more localized scenarios and our opponents are searching for, and finding, means of conflict which can avoid the technical superiority which the West continues to develop; for example, terrorism, ethnic cleansing, tribal warfare, use of food as a weapon, and threatening the use of weapons of mass destruction.

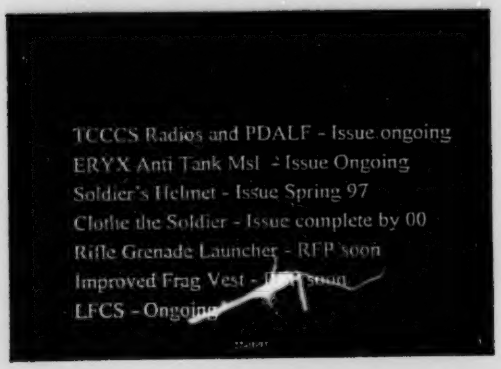
Canadian combat troops, along with the troops of other nations represented here, have experienced many of these tactics in the recent years in Somalia, Rwanda, northern Iraq, Croatia, Cambodia and currently in Haiti and Bosnia.

The Canadian Infantry, therefore, is as busy as it has ever been in a period of peace.

However, like many Western governments, the Canadian Government is reducing overall resources allocated to defence, but is making an effort to reallocate more defence resources to the army.

Our strategy in Canada, then, is to enhance the individual soldier's combat capabilities, along with those of his small unit, to meet these new challenges, while maintaining an army wide general purpose combat capability. The focus for equipment is on the soldier.

Our strategy can be easily described in two 5 year bands.


- TCCCS Radios and PDALF - Issue ongoing
- ERYX Anti Tank Msl - Issue Ongoing
- Soldier's Helmet - Issue Spring 97
- Clothe the Soldier - Issue complete by 00
- Rifle Grenade Launcher - RFP soon
- Improved Frag Vest - [illegible] soon
- LFCS - Ongoing

Before I discuss this slide I should remind you that Canada has recently completed its Small Arms Replacement Project with the Diemaco C7 family and has up-graded the NBC equipment with a new NBC respirator.

Over the next 5 years, there are seven projects coming to fruition which will directly affect the soldier and his section.

The fielding of a completely new combat net radio system, both mounted and dismounted, which includes a GPS based navigation aid is ongoing.

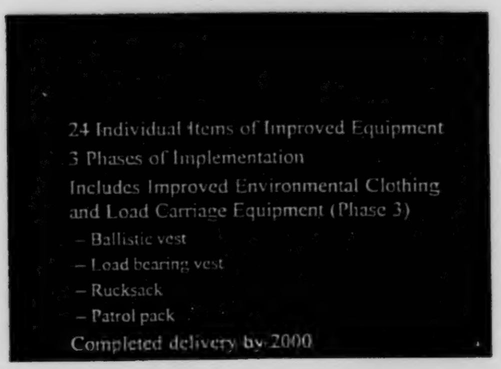
The ERYX short range anti-armour weapon system will increase the anti-armour punch of every rifle section.

Canada has contracted Gallet International of France to produce ballistic helmets in Canada with issue to troops commencing this spring.

The Clothe the Soldier project is a direct result of our recent experience in UNPROFOR, where equipment that was formerly only issued for operational use will become general issue.

Two rifle grenade launchers will be added to the rifle section shortly, and our current inventory of fragmentation vests will be modified to increase mobility and comfort.

Also of note is a major Command and Control System we call the Land Force


- 24 Individual Items of Improved Equipment
- 3 Phases of Implementation
- Includes Improved Environmental Clothing and Load Carriage Equipment (Phase 3)
  - Ballistic vest
  - Load bearing vest
  - Rucksack
  - Patrol pack
- Completed delivery by 2000

It is worthwhile to mention further the Clothe the Soldier Project.

This project is an omnibus project which brings together some 24 compatible items which are to be issued to a soldier.

Most of these items were fielded in our IFOR and UNPROFOR commitments but are not on general issue.

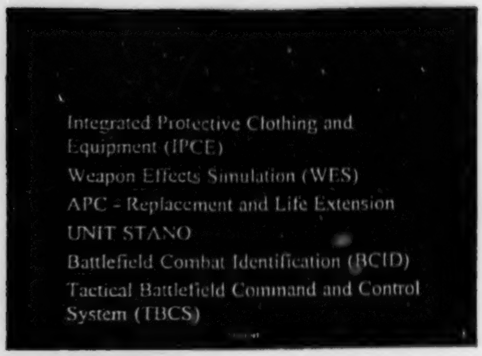
It will have a phased implementation with issue to troops completed by the year 2000.

It can be divided broadly in two areas:

Firstly, improved environmental clothing for extreme cold, cold wet and hot climates using the latest membrane technologies. This includes handwear, footwear and head-wear, and

Secondly, load carriage equipment which is designed "from the man out" to include a ballistic protection, a fighting order vest as well as a compatible rucksack of modular design.

Many elements of this equipment will be carried into the future as the baseline for performance, weight and bulk.



Integrated Protective Clothing and Equipment (IPCE)

Weapon Effects Simulation (WES)

APC - Replacement and Life Extension

UNIT STANO

Battlefield Combat Identification (BCID)

Tactical Battlefield Command and Control System (TBCS)

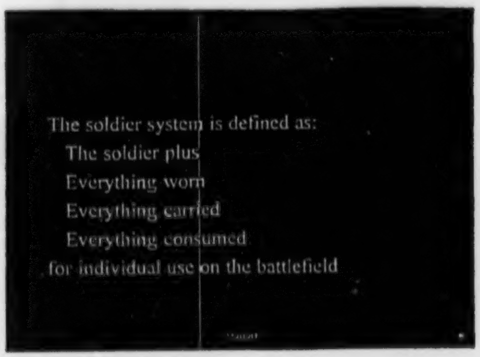
The next group of projects will come to fruition in the 6-10 year band.

The Integrated Protective Clothing and Equipment project seeks to field approximately 30,000 suites of integrated systems around the year 2005. I will discuss this in more detail later.

Two battlegroups worth of Weapon Effects Simulation will be fielded by 2002.

Up to 650 new APCs, MOWAG Gen 3 made by GM Diesel Division in Canada, may be purchased, - we have recently contracted for 240 -, and a further 1200 in service APCs will be upgraded in a life extension project.

The last three projects will improve, at Battalion level, the unit STA resources, the Battlefield Combat ID for vehicles and dismounted troops and establish the unit level command and control system which links the Land Force Command and Control System to IPCE.



The soldier system is defined as:

The soldier plus

Everything worn

Everything carried

Everything consumed

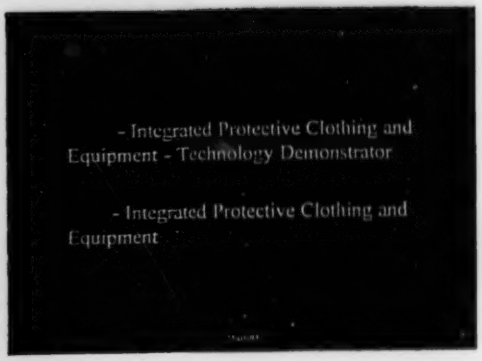
for individual use on the battlefield

Canada has been active in the NATO studies and uses this standard Soldier System definition.

This definition fits nicely with a soldier-centric viewpoint.

I would now like to focus on the second band of the Canadian strategy for Soldier Modernization, in particular on the Integrated Protective Clothing Equipment Project or IPCE, for the next few minutes.

The purpose of IPCE is to improve individual soldier protection and effectiveness by fielding an integrated protective clothing and equipment system.



- Integrated Protective Clothing and Equipment - Technology Demonstrator

- Integrated Protective Clothing and Equipment

It is divided into two projects, which embody the bulk of the soldier modernization work for the future in Canada.

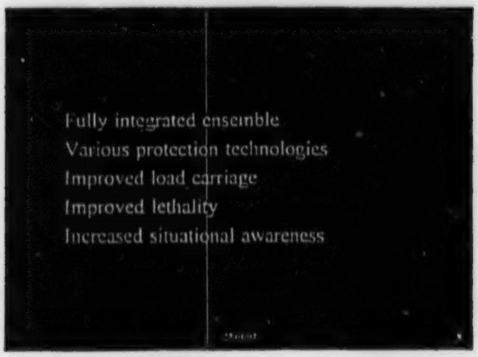
Project D6378, the R&D project, seeks to develop one platoons worth of advanced technology demonstrators for trial in the year 2000.

Project G2383, the capital project, seeks to provide 30,000 suites of equipment to the field force around the year 2005.

Both of these projects will glean significant input from the operational research and modeling which has been planned.

Canada has worked closely with our NATO allies on the NATO Industrial Advisory Group Pre-feasibility Study conducted by Sub-Group 48 and participates in activity WG3 of land Group 3 on Soldier Modernization.

WG4 of Land Group 3 is preparing to conduct additional modeling on the NATO soldier System.



Fully integrated ensemble

Various protection technologies

Improved load carriage

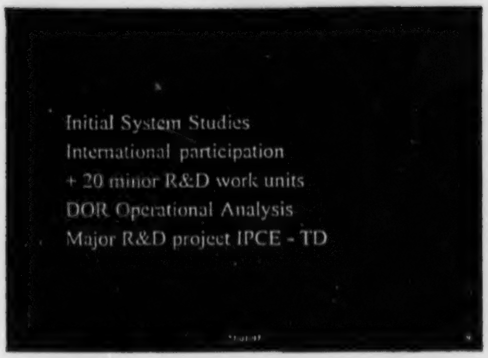
Improved lethality

Increased situational awareness

The scope of IPCE is as you see here.

Please note the emphasis on an integrated solution as opposed to Clothe the Soldier which seeks compatible solutions.

The project will not introduce a new personal weapon nor try to replace our new radio system. It may introduce a personal radio and computer.



Initial System Studies
International participation
+ 20 minor R&D work units
DOR Operational Analysis
Major R&D project IPCE - TD

In order to support this project, work is proceeding in 5 key areas;

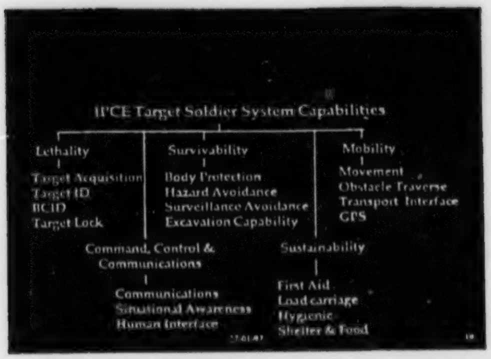
a. First , in July of 1995, an initial IPCE System Definition Project was completed in cooperation with Computing Devices Canada, which enunciated the future soldiers' threats, tasks and needs, the detailed requirements for the future suite of equipment and the current state of technology. These documents form the basis of our long term plan,and will be available upon request, once the current bid evaluation for our technology demonstrator is complete;

b. Second, international participation is ongoing with the NATO and ABCA working groups on soldier modernization, and TTCP Panel and bilateral memorandums of understanding on R&D with our major allies;

c. Third, over 20 minor R&D work units have been initiated in the DND R&D Thrust which supports IPCE. These include work such as the Advanced Load Carriage System, Ballistic Protection for IPCE and a human factors evaluation of Helmet Mounted Displays.

d.. Fourth, our Land Operational Research staff have commenced the operational analysis of IPCE which will study tactical impact and cost benefit. The data obtained by tests and trials will further refine and support the capital decision

e. And lastly, the ongoing activity of a 16 million dollar R&D project, the IPCE Technology Demonstrator, which I will discuss in more detail shortly.



IPCE Target Soldier System Capabilities

Lethality
- Target Acquisition
- Target ID
- BCID
- Target Lock

Survivability
- Body Protection
- Hazard Avoidance
- Surveillance Avoidance
- Excavation Capability

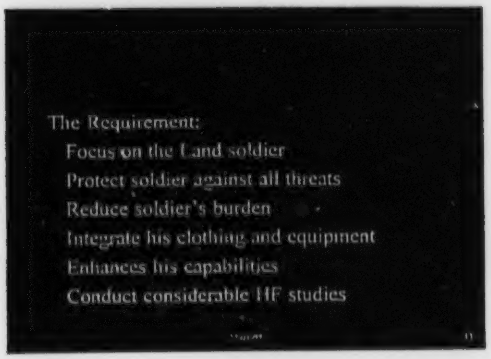
Mobility
- Movement
- Obstacle Traverse
- Transport Interface
- GPS

Command, Control & Communications
- Communications
- Situational Awareness
- Human Interface

Sustainability
- First Aid
- Load carriage
- Hygienic
- Shelter & Food

The 5 NATO defined capability areas are used to pursue improvements for the soldier system of the future. I will discuss each briefly.

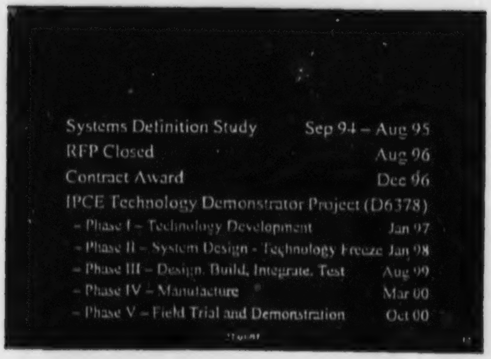
Improvements in lethality will be achieved without the introduction of a new weapon system. The increase in lethality will come from the fusion of data of an improved weapon sight , likely an uncooled thermal staring array, and laser range finder which presents a heads-up fire control solution for each weapon. The command and control system will likely see a personal radio, GPS and computer with mass storage with each soldier to provide vastly improved situational awareness. In terms of survivability the threats are well defined in the NATO Threat document for the Dismounted Soldier. Canada is currently conducting research into protection which will defeat flechettes and 12.7 mm sniper rounds and provide the full range of NBC protection . The integrated system will be based on considerable human factors study, which will contribute to the soldiers sustainability. All areas of a soldier system, including rations, the interfaces with his vehicle and load carriage will be studied. In addition to the improved integrated equipment, the application of GPS and stored map and trace displays will enable the future soldier an unparalleled level of mobility and situational awareness. We believe this can be done in a cost effective manner.



The Requirement:
- Focus on the Land soldier
- Protect soldier against all threats
- Reduce soldier's burden
- Integrate his clothing and equipment
- Enhances his capabilities
- Conduct considerable HF studies

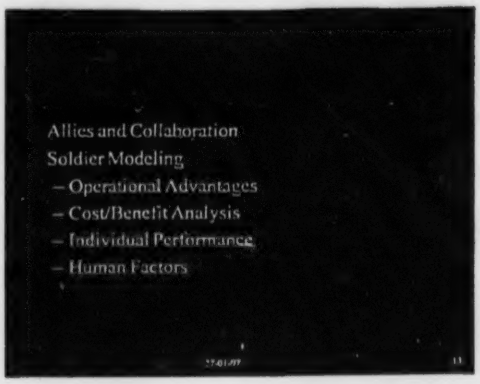
Now, back to the IPCE Technology Demonstrator.

Computing Devices Canada has been selected as the prime contractor in this major R&D project. A Ministerial announcement is expected shortly. The requirement is as you see here.



Systems Definition Study	Sep 94 – Aug 95
RFP Closed	Aug 96
Contract Award	Dec 96
IPCE Technology Demonstrator Project (D6378)	
– Phase I – Technology Development	Jan 97
– Phase II – System Design - Technology Freeze	Jan 98
– Phase III – Design, Build, Integrate, Test	Aug 99
– Phase IV – Manufacture	Mar 00
– Phase V – Field Trial and Demonstration	Oct 00

The milestones are as you see here. The first deliverable, the system study, is complete and has been accepted by our leadership.



- Allies and Collaboration
- Soldier Modeling
  - Operational Advantages
  - Cost/Benefit Analysis
  - Individual Performance
  - Human Factors

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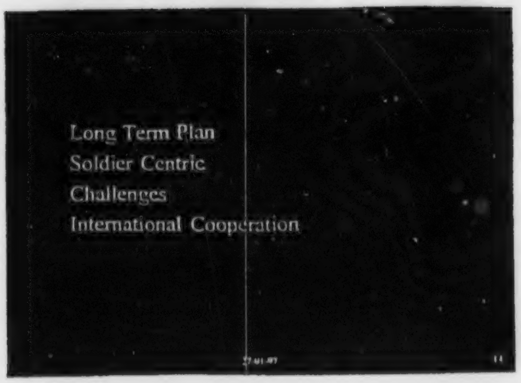
going Soldier Modernization operational research is headed by Ms Lisa
, who will be speaking this afternoon. The key elements of this
s, from the operator's perspective, are seen here.



- Long Term Plan
- Soldier Centric
- Challenges
- International Cooperation

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In summary, Canada has a comprehensive long-term plan.

Our focus is soldier-centric and will come to fruition over the next decade in two 5 year bands.

There are a number of technological challenges in the areas of small arms vs ballistic protection and the protective measures against non-lethal weapons.

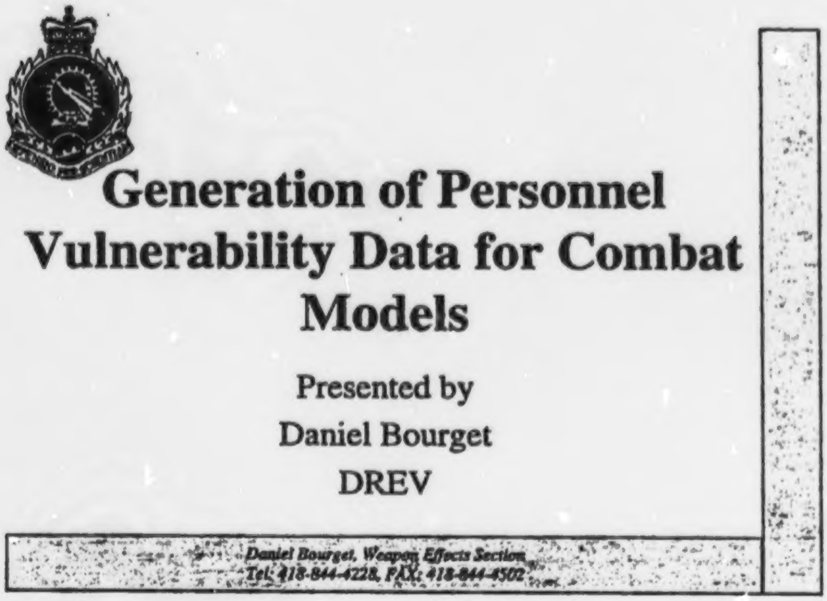
There are also challenges in relation to our soldiers; what is their capacity to absorb this technology.

We know it works in theory, and it has been demonstrated in the limited trials conducted by our allies. We even know that it works in operations with specialist troops in very limited and rehearsed engagements.

What we do not yet know, is the degree it will all work in general service with the broad population of soldiers, typically living and operating in an encapsulated environment over extended periods of stress, lasting days and weeks. This will involve considerable operational research.

Canada in cooperation with our allies is keen to address these challenges.

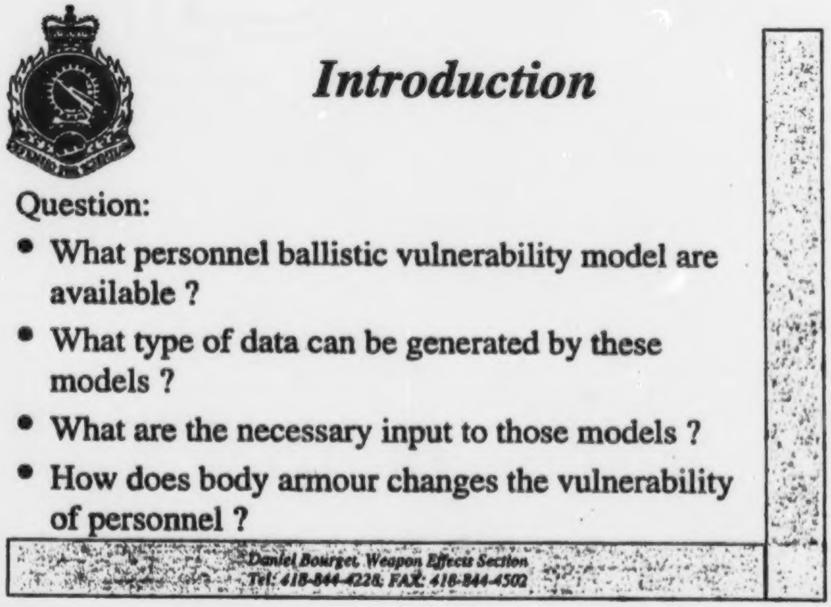
This concludes my presentation. I believe there is a short period available for questions. Thank you.



Generation of Personnel Vulnerability Data for Combat Models

Presented by
Daniel Bourget
DREV

Daniel Bourget, Weapon Effects Section
Tel: 418-844-4228, FAX: 418-844-4502



Introduction

Question:

- What personnel ballistic vulnerability model are available ?
- What type of data can be generated by these models ?
- What are the necessary input to those models ?
- How does body armour changes the vulnerability of personnel ?

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Overview

- Personnel vulnerability inputs to combat models.
- Human ballistic vulnerability models and methodologies available.
- Experimental testing for human ballistic vulnerability models.
- Examples.
- Conclusions.

Personnel Ballistic Vulnerability Inputs to Combat Models

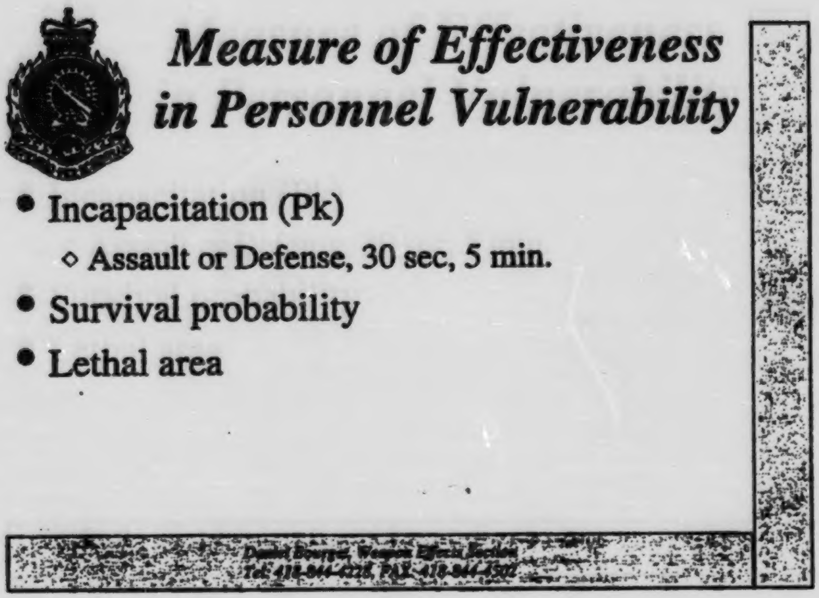
- HE warheads:
  - ◇ Kill radius or area for a specific weapon.
- Bullets:
  - ◇ External ballistic (Range-velocity-elevation) for a specific munition
  - ◇ Kill probability for a specific munition with varying ranges, relative motion and impact azimuth.

Personnel Ballistic Vulnerability Inputs to Combat Models

- Mines:
  - ◇ Kill probability for one mine type against different target for the mine effective trip radius or the mine detonation radius.

Remarks

- All kill probabilities are Pk given a hit. (weapon independant)
- Personnel is always viewed as a single block.
- Kill probabilities and lethal areas will vary with the threat and the armour (material used, coverage area, terrain shielding)



Measure of Effectiveness in Personnel Vulnerability

- Incapacitation (Pk)
    - ◇ Assault or Defense, 30 sec, 5 min.
- Survival probability
- Lethal area

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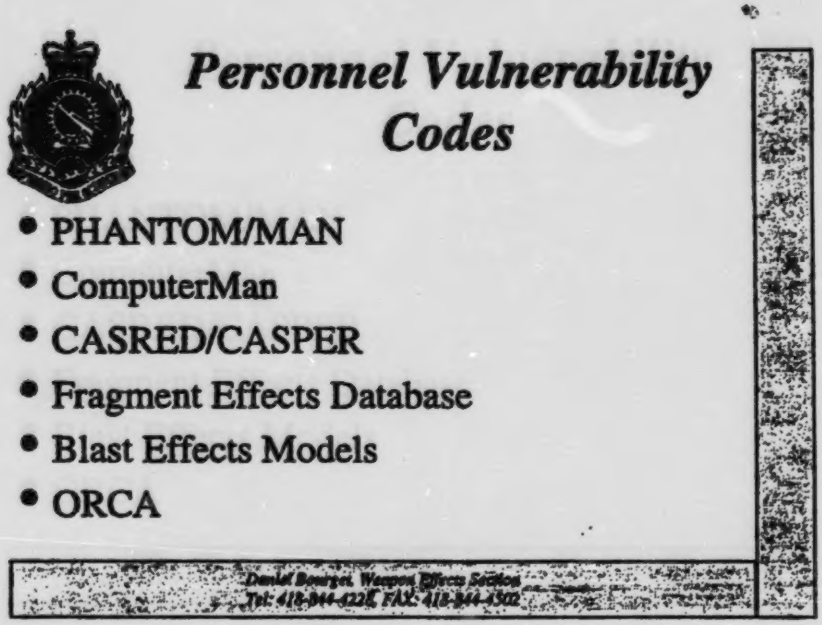

Personnel Vulnerability Codes

- PHANTOM/MAN
- ComputerMan
- CASRED/CASPER
- Fragment Effects Database
- Blast Effects Models
- ORCA

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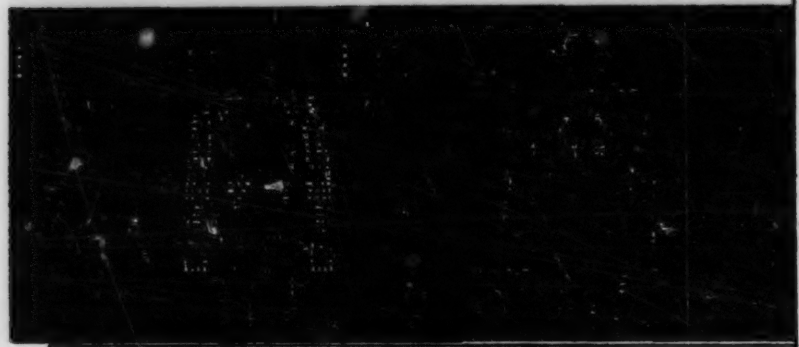
PHANTOM/MAN

- Timberwolf (Netherland)
- Deals with bullets, fragments and flechettes
- Uses an anatomical database and a medical expert system to assess incapacitation.
- Armour protection can be added to different body area.

ComputerMan

- ComputerMan (US, ARL)
- Deals with fragments only. For LFT
- Uses an anatomical database and an operational expert database to assess incapacitation.
- Limited protection can be added (to certain body area only). No terrain shielding

Typical ComputerMan Output



Incapacitation

Survival Probability

CASPER/CASRED

- CASRED (US, AMSAA) and CASPER (UK, DCTA). For CRA
- CASPER and CASRED incapacitation data are based on ComputerMan (or its ancestor) output.
- Deals with fragment effects of HE warheads and mines.
- Protection and terrain shielding allowed

Blast Models

- Used for HE warhead and mine threats.
- U.S. work on INJURY (WRAIR)
  - Mathematical/biomechanical model relating experimental data to incapacitation.
- U.K. work on the thoracic rig (CBDE)
  - Experimental model relating to incapacitation.

ORCA

- Operational Requirement-Based Casualty Assessment. (CCWG, JTCG/ME and AS)
- Deals with fragments, blast, heat, acceleration, chemical insults.
- Integrate multiple insults all together to give an overall incapacitation
- No armour protection can be added.

Personnel Ballistic Vulnerability Model Inputs

- Weapons characteristics
  - ◇ Bullets
    - impact velocity, shape, material, physical dimensions
  - ◇ HE warheads/mines (fragments)
    - Bursting velocity, frag. initial velocity, orientation with respect to personnel, drag coefficient, frags. mass and density distribution. Data provided by Arena tests.

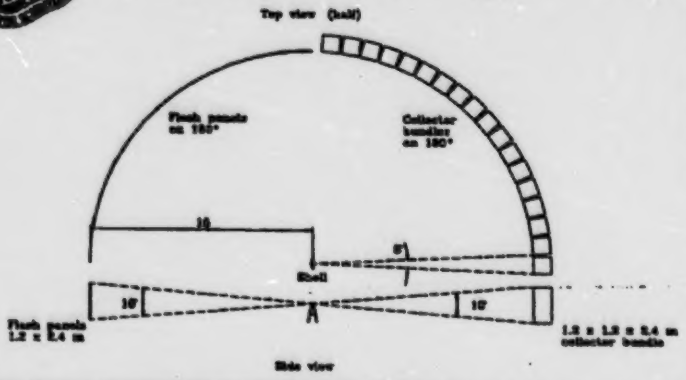
Personnel Ballistic Vulnerability Model Inputs

- Body armour characteristics
  - ◇ Body area covered with protection
  - ◇ Terrain shielding
  - ◇ Ballistic protection provided by
    - Ballistic Limit
    - Vs-Vr curves (0 and 45 deg.)
    - Varies with bullet/fragment size and shape:

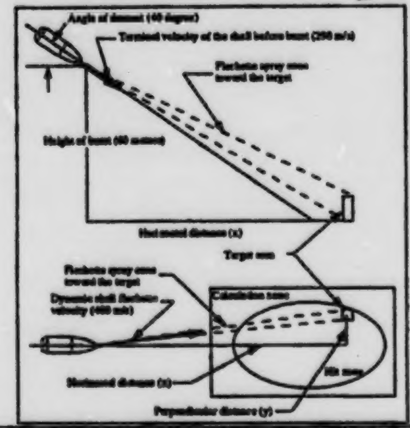
Ballistic Protection: Generation of Input Data

- Vs-Vr curves (for 1 material of specific thickness):
  - For 4 fragment sizes (RCC), 2 impact angle, need to fire 30 shots per angle and fragment sizes.
  - Curve fitting of the raw data.
- Ballistic limit (for 1 material of specific thickness):
  - Between 6 and 15 shots with 1 or 2 fragment size (V_{50})
  - Much more shots needed for other penetration probability e.g. V_5, V_{10}

Fragmentation (Arena test): Generation of Input Data


Top view (half)
Flash panels on 180°
Collector bundles on 180°
10
5°
Shell
10°
10°
Flash panels 1.2 x 2.4 m
1.2 x 1.2 x 2.4 m collector bundle
Side view

Flechette Example


Angle of descent (40 degree)
Terminal velocity of the shell before burst (250 m/s)
Flechette spray cone toward the target
Height of burst (60 meters)
Horizontal distance (x)
Target area
Flechette spray cone toward the target
Dynamic shell flechette velocity (400 m/s)
Calculation zone
Horizontal distance (x)
Hit zone
Perpendicular distance (y)

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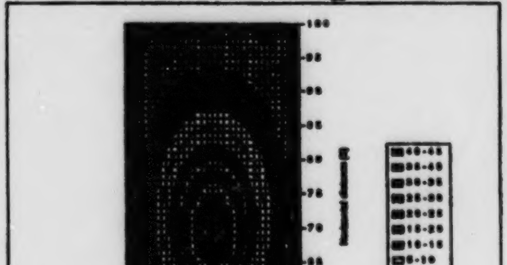
Flechette Example *(# of hit)*



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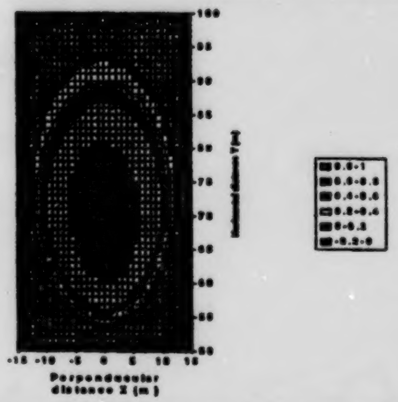
Flechette Example (P kill area)



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Flechette Example

(protection comparaison)

Body Armor System	AD kg/m²	V_{50} m/s	Area for 100 % P_k	
			Assault 30 sec.	Assault 5 min.
A) Unprotected	0.00	0.00	32.7	56.0
B) Fabric	3.86	92.8	31.4	56.0
C) Fabric +3.18 mm Al	13.00	225.8	29.6	53.2
D) Fabric +1.59 mm Ti	11.02	391.5	22.6	36.0

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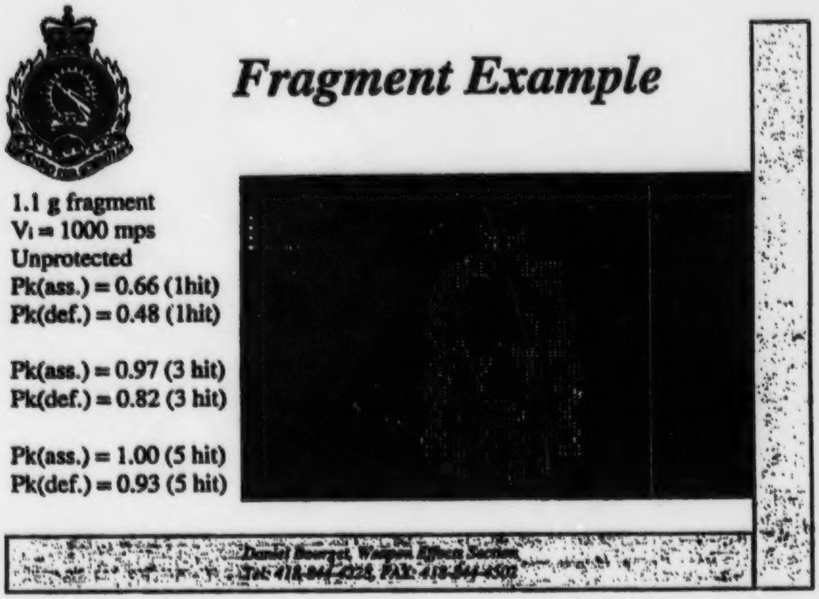

Fragment Example

1.1 g fragment
V_i = 1000 mps
Unprotected
Pk(ass.) = 0.66 (1hit)
Pk(def.) = 0.48 (1hit)

Pk(ass.) = 0.97 (3 hit)
Pk(def.) = 0.82 (3 hit)

Pk(ass.) = 1.00 (5 hit)
Pk(def.) = 0.93 (5 hit)

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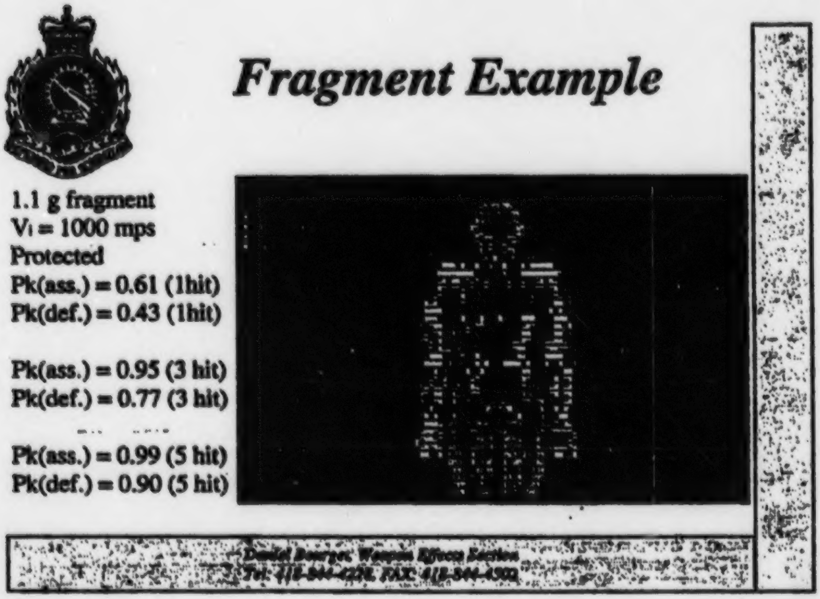

Fragment Example

1.1 g fragment
V_i = 1000 mps
Protected
Pk(ass.) = 0.61 (1hit)
Pk(def.) = 0.43 (1hit)

Pk(ass.) = 0.95 (3 hit)
Pk(def.) = 0.77 (3 hit)

Pk(ass.) = 0.99 (5 hit)
Pk(def.) = 0.90 (5 hit)

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Conclusion

- Human ballistic vulnerability programs are an important step between experimental data and Combat Models.
- It is necessary to well define:
    - ◇ The weapon
    - ◇ The protection
- The data generated by human ballistic vulnerability programs are valid only for a well defined set of protection-weapon.
- Potential of being included into higher order Combat models

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DRES

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD

Medicine Hat, Alberta
Canada

DRES

Materials/Thermal Strain and Body Region Hazard Assessment Models at DRES

Dr Scott Duncan
Physical Protection Section
Defence Research Establishment Suffield

DRES

BODY REGION HAZARD AND TOXICITY ASSESSMENT MODEL

(A COMPONENT OF THE INTEGRATED PROTECTIVE ENSEMBLE IN A VAPOUR ENVIRONMENT (IPEVAPOUR) SYSTEMS TEST

DRES

TRADITIONAL CB PROTECTION TEST AND EVALUATION METHODS

- PENETRATION OF CHEMICAL AGENTS THROUGH SAMPLES OF FABRIC
- IF PENETRATION IS LESS THAN CRITICAL LEVEL SPECIFIED, PROTECTION DEEMED ADEQUATE (HOWEVER, NO INFO ON PROTECTIVE CAPABILITY OF IPE AS A SYSTEM)
- LIVE AGENT FIELD TRIALS WITH TONS OF AGENT

TRADITIONAL METHODS FAIL TO PROVIDE A QUANTITATIVE EVALUATION OF THE PROTECTIVE CAPABILITY OF THE IPE SYSTEM

DRES

GOAL OF CB PROTECTIVE RESEARCH

- REPLACE LIVE AGENT FIELD TRIALS WITH A SYSTEMS TEST AND EVALUATION METHODOLOGY USING CHEMICAL AGENT SIMULATES
  - APPLY HAZARD ASSESSMENT MODEL THAT PERMITS DISCRIMINATION BETWEEN, AND RANKING OF, DIFFERENT IPE CONCEPTS
- DEVELOP CB IPE'S WITH **OPTIMUM BALANCE** BETWEEN PROTECTION AND OPERATIONAL CAPABILITY

DRES

ASSESSING EFFECTIVENESS OF CB PROTECTIVE ENSEMBLES

- ACCEPT THAT SOME UNCERTAINTY IS INHERENT IN ANY DESIGN
- TWO APPROACHES
  - ACTUAL CHEMICAL AGENTS AND MANNEQUINS (BOTH STATIC AND ACTIVE)
  - CHEMICAL AGENT SIMULANTS AND HUMANS

DRES

TOXICITY LEVELS INSIDE A CB IPE ARE DETERMINED BY THE PENETRATION OF THE CHEMICAL THROUGH, AND THE TRANSPORT WITHIN, THE IPE SYSTEM

DRES

- AGENT PENETRATION OF IPE IS A FUNCTION OF
  - FABRIC
  - CLOSURES
  - *HUMAN ACTIVITY LEVEL*
- AGENT TRANSPORTATION WITHIN IPE IS A FUNCTION OF
  - AIR LAYER THICKNESS
  - DIFFUSION
  - CONVECTION
  - ENVIRONMENTAL CONDITIONS (TEMP, HUMIDITY)
  - *HUMAN ACTIVITY LEVEL*

CANADIAN APPROACH (within TTCP SGE TP-11)

- INTEGRATED PROTECTIVE ENSEMBLE IN A VAPOUR ENVIRONMENT SYSTEMS TEST
  - HUMAN PARTICIPANTS
  - CHEMICAL AGENT SIMULANT
  - UNDER-THE-SUIT PASSIVE ADSORBENT SAMPLERS
  - PHYSICAL ACTIVITY REGIME (*TO EXERCISE THE IPE*)
  - INCORPORATION OF A BODY REGION HAZARD AND TOXICITY ASSESSMENT MODEL
    - CONSIDERS THE VARIATION IN SENSITIVITY TO CHEMICAL AGENT EXPOSURE AT DIFFERENT REGIONS ON THE BODY

BODY REGION HAZARD AND TOXICITY ASSESSMENT MODEL

- METHODOLOGY FOR EVALUATING THE PROTECTIVE CAPABILITY OF NBC PROTECTIVE ENSEMBLES
  - BODY DEFINED INTO DISCRETE REGIONS .
  - MASS ABSORBED AT EACH REGION WITH AND WITHOUT NBC PROTECTION
  - TAKES INTO ACCOUNT THE REGIONAL VARIATION IN SENSITIVITY TO CHEMICAL AGENT EXPOSURE AT EACH REGION ON THE BODY
  - LOCAL VAPOUR EFFECTS ANALYSIS FOR AGENTS SUCH AS HD (MUSTARD)
  - SYSTEMIC VAPOUR EFFECTS ANALYSIS FOR AGENTS SUCH AS VX (NERVE)
- UNDERLYING THEORY ORIGINALLY PROPOSED BY DR PAUL FEDELE, US ARMY ERDEC.
- TOXICITY ASSESSMENT PROPOSED BY DR SCOTT DUNCAN (DRES) AND DR EVA DICKSON (RMC)

TOXICOLOGICAL FRAMEWORK

- PROBABILITY OF EXHIBITING A SYMPTOM OF A CERTAIN SEVERITY IS RELATED TO THE DOSE OF TOXIC MATERIAL
- PROBABILITY OF A REACTION GIVEN IN TERMS OF NORMAL DEVIATE ABOUT THE MEAN RESPONSE
- WE ASSUME A LINEAR RELATIONSHIP BETWEEN LOG OF DOSE AND NORMAL DEVIATE

$$S = n\log(D) + b \qquad (1)$$

WHERE *S* IS THE NORMAL DEVIATE, *D* IS THE DOSE AND *n* AND *b* ARE CONSTANTS.

- FOR THE MEAN RESPONSE DOSE D_{50}, S=0 AND

$$b = -n\log(D_{50}) \qquad (2)$$

- ASSUME THAT A RESPONSE TO A CHEMICAL AGENT EXPOSURE IS DETERMINED BY THE QUANTITY OF AGENT FIXED TO SITES OF ACTION IN THE BODY (M_p), THEN WE CAN WRITE

$$S = n'\log(M_p) + b \qquad (3)$$

- SUBSTITUTING Eq 2 INTO Eq 3 WE HAVE

$$S = n'\log\left(\frac{M_p}{M_{p50}}\right) \qquad (4)$$

WHERE M_{p50} IS THE AMOUNT OF FIXED AGENT CORRESPONDING TO A MEAN RESPONSE

- IN A SYSTEMS TEST THE ENTIRE BODY WILL BE EXPOSED TO A DISTRIBUTED DOSE. THE ELEMENT OF DOSE DELIVERED OVER A FINITE BODY REGION *l* IS

$$dM_l = m_l dz_l \qquad (5)$$

WHERE m_l IS THE AVERAGE MASS PER UNIT AREA dz_l

- THE TOTAL AMOUNT OF AGENT FIXED TO SITES OF ACTION AS A RESULT OF A DISTRIBUTED DOSE IS

$$M_{p_{tot}} = \sum_{l=1} \varepsilon_l m_l dz_l \qquad (6)$$

- SUBSTITUTING $M_{p_{tot}}$ IN Eq 6 INTO Eq 4, THEN FOR THE MEAN RESPONSE *S*=0 WE ARRIVE AT

$$M_{p50} = \sum_{l=1} \varepsilon_l m_l dz_l \qquad (7)$$

- MUST EITHER DEFINE ε_l's OR REPLACE WITH MEASURABLE DOSES
- ASSUME THE CASE WHERE ONLY 1 INDIVIDUAL DOSE CAUSING A MEAN RESPONSE IS DELIVERED TO THE BODY REGION *j*. REPLACING THE *l*'s IN Eq 6 WITH *j*'s AND SUBSTITUTING INTO Eq 4 , THEN FOR THE MEAN RESPONSE *S*=0

$$M_{p50} = \varepsilon_j m_j dz_j = \varepsilon_j M_{j50} \qquad (8)$$

- REPLACING *j*'s IN Eq 8 WITH *l*'s AND SUBSTITUTING Eq 6 AND Eq 8 INTO Eq 4 WE HAVE

$$S = n\log\left(\sum_{l=1} \frac{m_l dz_l}{M_{l50}}\right) \qquad (9)$$

WHERE m_l IS THE AVERAGE MASS PER UNIT AREA dz_l IN EACH BODY REGION *l* AND M_{l50} IS THE INDIVIDUAL DOSE THAT CAUSES A MEAN RESPONSE

- RELATIONSHIP BETWEEN MASS CAUSING MEAN RESPONSE AT EACH BODY REGION AND THE CONCENTRATION-TIME DOSAGE IS

$$M_{l50} = Ct_{l50} U_{m_l} dz_l \qquad (10)$$

WHERE U_{m_l} IS THE MASS UPTAKE RATE ASSOCIATED WITH EACH BODY REGION

- MASS DELIVERED TO EACH BODY REGION *l* IN THE ABSENCE OF PROTECTIVE CLOTHING

$$M_{l(np)} = Ct_{ext} U_{m_l} dz_l \qquad (11)$$

- SUBSTITUTING Eq 10 INTO Eq 9 AND MULTIPLYING THE NUMERATOR IN Eq 9 BY THE RIGHT HAND SIDE OF Eq 11 AND THEN DIVIDING BY THE LEFT HAND SIDE OF Eq 11 WE ARRIVE AT

$$S = n\log\left(\sum_{l=1} \frac{\dfrac{Ct_{ext} U_{m_l} dz_l}{M_{l(np)}} m_l dz_l}{Ct_{l50} U_{m_l} dz_l}\right) \qquad (12)$$

WHICH REDUCES TO

$$S = n\log\left(\sum_{l=1} \frac{Ct_{ext}}{Ct_{l50}} \frac{1}{Pf_l}\right) \qquad (13)$$

WHERE

$$Pf_l = \frac{M_{l(np)}}{m_l dz_l} \qquad (14)$$

IS THE PROTECTION FACTOR

- Eq 13 MAY BE RE-WRITTEN AS

$$Ct_{ext50} = \frac{1}{\left(\sum_{i=1} \frac{1}{Pf_i Ct_{i50}}\right)} \quad (15)$$

WHERE Ct_{ext50} IS THE EXTERNAL VAPOUR CHALLENGE THAT WILL CAUSE A MEAN SYMPTOM REACTION WHEN AN INDIVIDUAL IS WEARING COMPLETE NBC PROTECTION

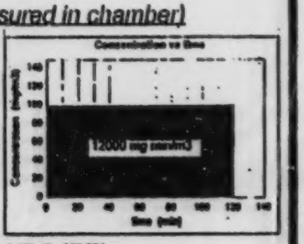
PROTECTION FACTOR

$$Pf = \frac{M_{out}}{M_{in}} \quad (1)$$

- M_{out} = MASS MEASURED BY PASSIVE ADSORBENT SAMPLERS WHEN NO PROTECTION IS USED
- M_{in} = MASS MEASURED BY PASSIVE ADSORBENT SAMPLERS INSIDE NBC PROTECTIVE ENSEMBLE

CONCENTRATION-TIME DOSAGE (*Ct*)

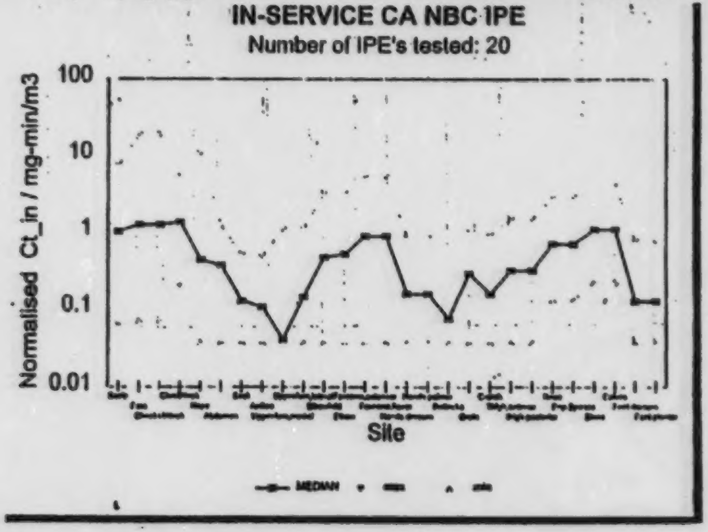
EXTERNAL Ct VAPOUR CHALLENGE (measured in chamber)



$$Ct_{ext} = C_{ext} \cdot t \ \ (\text{mg min m}^{-3}) \quad (2)$$

INTERNAL Ct VAPOUR CHALLENGE (inside NBC IPE)

$$Ct_{in} = \frac{Ct_{ext}}{Pf} \qquad (\text{mg min m}^{-3}) \qquad (3)$$



LOCAL VAPOUR EFFECTS HAZARD AND TOXIC ASSESSMENT (HD)

- LOCAL REACTION
  - WHEN AN INDIVIDUAL DOSE SPECIFIC TO ONE REGION OF THE BODY CAUSES A REACTION ONLY AT THAT REGION, THEN THE REACTION IS SAID TO BE LOCAL (doses specific to regions do not contribute to the reactions at other regions)

LOCAL VAPOUR EFFECTS HAZARD ANALYSIS (HD)

- EFFECTIVE Ct_{ext50} (mg min m^{-3})
  - EXTERNAL VAPOUR EXPOSURE FOR HD CAUSING MEAN REACTION

$$Ct_{ext50} = VX_{ED(50)} \cdot K_1/K_2 \cdot Pf, \qquad (4)$$

WHERE K_1 AND K_2 ARE THE KNOWN UNPROTECTED HD VAPOUR EXPOSURE AND VX LIQUID EXPOSURE RESPECTIVELY, CAUSING A MEAN REACTION AT A SPECIFIC REGION

  - Eq 1 APPLIED TO EACH REGION OF THE BODY
  - CRITICAL: EFFECTIVE Ct_{ext50} FOR A NBC PROTECTIVE ENSEMBLE IS THE LOWEST Ct DETERMINED FOR ALL BODY REGIONS

LOCAL VAPOUR TOXIC DOSE ASSESSMENT (HD)

- LOCAL Ct_{int50} (mg min m^{-3})
  - INTERNAL VAPOUR EXPOSURE FOR HD CAUSING MEAN REACTION

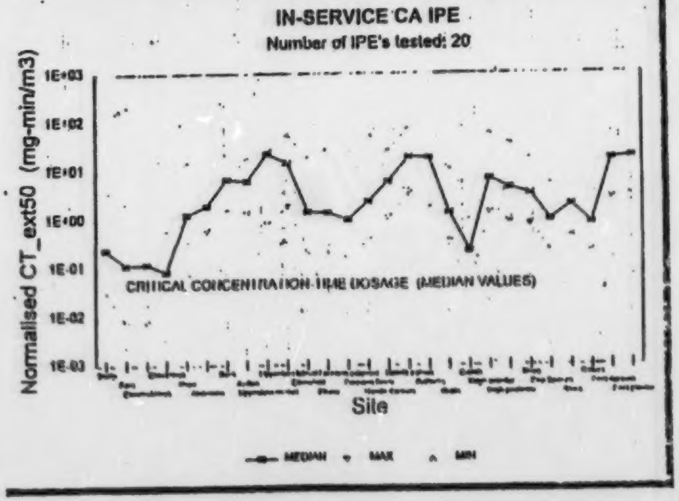
$$Ct_{int50} = VX_{ED(50)} \cdot K_1/K_2 \qquad (5)$$

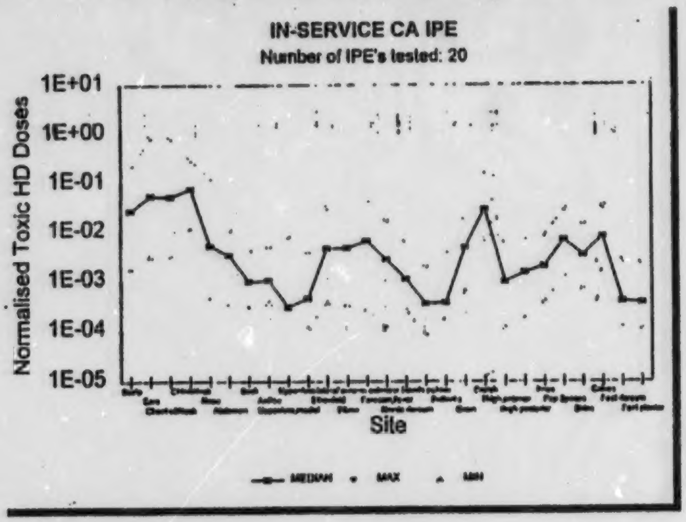
WHERE K_1 AND K_2 ARE THE KNOWN UNPROTECTED HD VAPOUR EXPOSURE AND VX LIQUID EXPOSURE RESPECTIVELY, CAUSING A MEAN REACTION AT A SPECIFIC REGION

  - APPLIED AT EACH REGION OF BODY

- HD TOXIC DOSE

$$HD_{TD} = Ct_{in} / Ct_{int50} \qquad (6)$$





SYSTEMIC VAPOUR EFFECTS HAZARD AND TOXIC DOSE ASSESSMENT (VX)

- SYSTEMIC REACTION
  - INDIVIDUAL DOSES AT DIFFERENT REGIONS OF THE BODY EACH CONTRIBUTE TO THE PROBABILITY OF A SYMPTOM AND THE TOTAL DOSE CAN BE CONSIDERED THE DIRECT SUM OF ALL THE INDIVIDUAL DOSES
  - REGIONAL VARIATION IN SENSITIVITY TO CHEMICAL AGENT EXPOSURE AT EACH REGION ON THE BODY DERIVED FROM WORK BY SIM (1962) USING LIQUID VX ON HUMANS

SYSTEMIC VAPOUR EFFECTS HAZARD ANALYSIS (VX)

- THE RELATIONSHIP BETWEEN *Ct* VAPOUR DOSAGE AT EACH BODY REGION *I* AND MASS ABSORBED FROM A LIQUID VX EXPOSURE AT THE SAME REGION *I*, CAUSING A MEAN REACTION, IS DEFINED AS

$$Ct_{I50} = \frac{KM_{I50}}{dz_I} \qquad (1)$$

WHERE *K* IS A PROPORTIONALITY CONSTANT, M_{I50} IS THE MASS ABSORBED AT EACH BODY REGION CAUSING A MEAN REACTION AND dz_I IS THE AREA OF EACH BODY REGION

SYSTEMIC VAPOUR EFFECTS HAZARD ANALYSIS (VX)

- THE EXPRESSION FOR EXTERNAL VAPOUR EXPOSURE CAUSING A MEAN REACTION IS

$$Ct_{ext50} = \frac{1}{\left[\sum_{I=1} \frac{1}{Pf_I\, Ct_{I50}}\right]} \qquad (2)$$

- SUBSTITUTING Eq 1 INTO 2 WE HAVE

$$Ct_{ext50} = \frac{1}{\left[\sum_{I=1} \frac{dz_I}{Pf_I\, K\, M_{I50}}\right]} \qquad (3)$$

- FOR ZERO PROTECTION, Pf_I=1, THEN

$$Ct_{ext50} = Ct_{50(np)} = \frac{1}{\left[\sum_{I=1} \frac{dz_I}{K\, M_{I50}}\right]} \qquad (4)$$

SYSTEMIC VAPOUR EFFECTS HAZARD ANALYSIS (VX)

- SOLVING FOR K,

$$K = Ct_{50(np)}\left[\sum_{l=1} \frac{dz_l}{M_{l50}}\right] \tag{5}$$

- REPLACING THE DUMMY INDICE l IN Eq 5 WITH j AND SUBSTITUTING Eq 5 INTO Eq 1 WE HAVE

$$Ct_{l50} = Ct_{50(np)}\left[\sum_{j=1} \frac{dz_j}{M_{j50}}\right]\left(\frac{M_{l50}}{dz_l}\right) \tag{6}$$

- Eq 6 IS THEN SUBSTITUTED INTO Eq 2 TO GIVE

$$Ct_{ext50} = \frac{1}{\left[\sum_{l=1} Pf_l Ct_{50(np)}\left[\sum_{j=1} \frac{dz_j}{M_{j50}}\right]\left(\frac{M_{l50}}{dz_l}\right)\right]} \tag{7}$$

SYSTEMIC VAPOUR EFFECTS HAZARD ANALYSIS (VX)

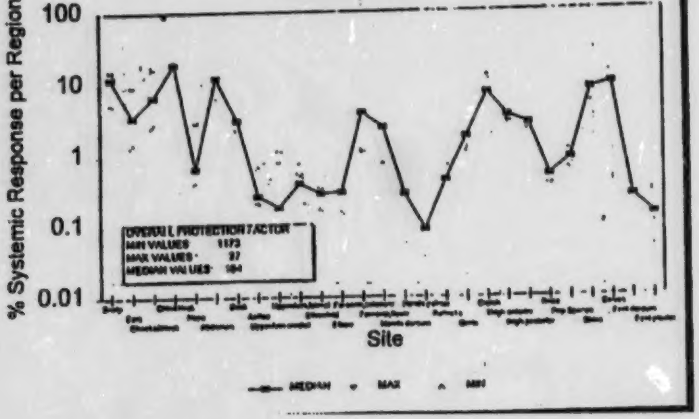
- REWRITING Eq 7 WE ARRIVE AT THE EXTERNAL VAPOUR EXPOSURE ANTICIPATED TO PRODUCE MEAN RESPONSE WHEN THE BODY EXHIBITS REGIONAL SENSITIVITY TO CHEMICAL AGENT DEPOSITIONS REPRESENTED BY M_{l50}

$$Ct_{ext50} = \frac{Ct_{50(np)}\sum_{l=1}\left(\frac{dz_l}{M_{l50}}\right)}{\sum_{l=1}\left[\frac{dz_l}{Pf_l M_{l50}}\right]} \tag{8}$$

- WITH THIS EXPRESSION WE CAN EVALUATE REGIONAL SENSITIVITY EFFECTS IN VAPOUR EXPOSURES WITH THE SAME RELATIVE VARIATIONS OBSERVED FOR LIQUID EXPOSURES
- BY MAKING Ct_{np50} COMPLETELY ARBITRARY, WE HAVE A COMPLETELY RELATIVE RANKING OF THE PROTECTIVE CAPABILITY OF THE IPE

IN-SERVICE CA NBC IPE

Number of IPE's tested: 20



SYSTEMIC VAPOUR EFFECTS TOXIC DOSE ASSESSMENT (VX)

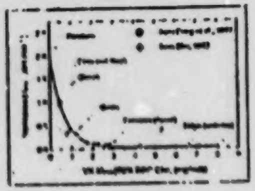
- SIM'S DATA ON REGIONAL SKIN SENSITIVITY TO LIQUID VX
  - PENETRATION FACTOR BASED ON 70% RBC Che INHIBITION vs ACCUMULATED DOSE FROM INTRAVENOUS INJECTION OF VX (KIMURA et al, 1960)
- ASSUME AREA OF VX DROPLET
- DETERMINE FRACTION OF VX THAT PENETRATED SKIN TO CAUSE A MEAN REACTION (g cm^{-2})
- DETERMINE FLUX (g cm^{-2} min^{-1})
- ASSUME LIQUID DROPLET OF VX IS EQUIVALENT TO SATURATED VAPOUR - CALCULATE VOLATILITY OF VX AT SKIN TEMP (g cm^{-3})
- ESTIMATE MASS UPTAKE RATE (U_m, (cm min^{-1})) FROM

$$U_m = \frac{Flux}{Volatility} \tag{1}$$

DRES

SYSTEMIC VAPOUR EFFECTS TOXIC DOSE ASSESSMENT (VX)

- AN EMPIRICAL RELATIONSHIP EXISTS BETWEEN SIM'S REGIONAL SENSITIVITY VALUES FOR LIQUID EXPOSURE OF VX (M_{I50}) AND MASS UPTAKE RATE (U_m)



$$U_{m_i} = A_1 \exp(A_2 M_{I50}) + A_3 \qquad (2)$$

WHERE A_1, A_2 AND A_3 ARE CONSTANTS

  - USED TO DETERMINE VALUES FOR U_m AT REGIONS NOT INVESTIGATED IN SIM'S STUDY

DRES

SYSTEMIC VAPOUR EFFECTS TOXIC DOSE ASSESSMENT (VX)

- CALCULATE MASS ABSORBED AT EACH BODY REGION *i* FROM THE RELATIONSHIP

$$M_i = Ct_{in_i} \cdot U_{m_i} \cdot A_i \qquad (3)$$

WHERE M_i IS THE MASS ABSORBED AT EACH BODY REGION, Ct_{in_i} IS THE CONCENTRATION-TIME DOSAGE CALCULATED UNDER THE SUIT, U_{m_i} IS THE MASS UPTAKE RATE AND A_i IS THE AREA OF THE BODY REGION

DRES

SYSTEMIC VAPOUR EFFECTS TOXIC DOSE ASSESSMENT (VX)

- VX TOXIC DOSE ESTIMATED AT EACH BODY REGION *i* FOR GIVEN CHAMBER *Ct* VAPOUR EXPOSURE

$$VX_{TDch_i} = \frac{M_i}{VX_{70CheTD}} \qquad (4)$$

WHERE M_i IS THE MASS ABSORBED AT EACH BODY REGION CAUSING A MEAN REACTION AND $VX_{70CheTD}$ IS THE INTRAVENOUS DOSE THAT CAUSES 70% RBC Che INHIBITION (mg/ind)

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SYSTEMIC VAPOUR EFFECTS TOXIC DOSE ASSESSMENT (VX)

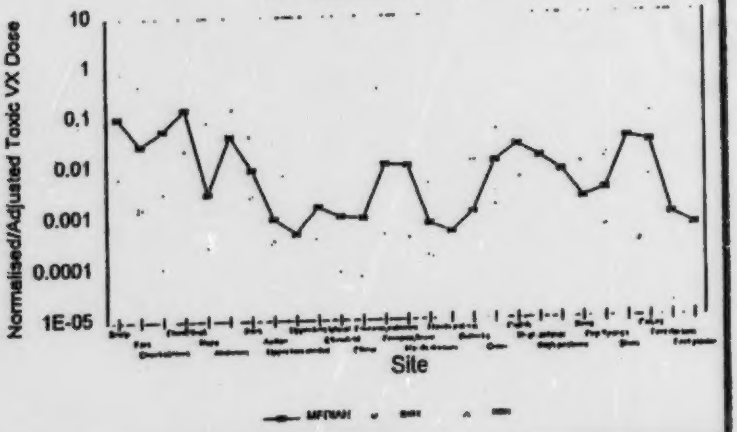
- Eq 4 CAN BE ADJUSTED TO A REALISTIC FIELD CHALLENGE VAPOUR EXPOSURE BY

$$VX_{TDa_i} = \frac{VX_{TDch_i} Ct_{fd}}{Ct_{ch}} \qquad (5)$$

WHERE VX_{TDa_i} IS THE VX TOXIC DOSE ADJUSTED FOR A REALISTIC FIELD VAPOUR CHALLENGE, VX_{TDch_i} IS FROM Eq 4, Ct_{fd} IS THE REALISTIC FIELD VAPOUR CHALLENGE AND Ct_{ch} IS THE CHAMBER VAPOUR CHALLENGE

IN-SERVICE CA NBC IPE

Number of IPE's tested 20



DRES

MODELLING THE THERMAL RESPONSE TO NBC PROTECTIVE CLOTHING

DEFENCE RESEARCH ESTABLISHMENT SUFFIELD CONTRACT
TO
M.E.T.A. Research Inc.
101-3840 Jacombs Road
Richmond, B.C.
V6V 1Y6

DRES

PURPOSE

- A MODEL WHICH PREDICTS HEAT STRESS IN CB CLOTHING BASED ON MATERIAL PROPERTIES.
- A USER-FRIENDLY COMPUTER PROGRAM TO ASSIST MATERIAL AND CLOTHING DEVELOPERS.
- A MODEL WHICH GIVES THE PHYSICS OF HEAT LOSS AS EXACTLY AS POSSIBLE.
- A MODEL WHICH TREATS PHYSIOLOGY WELL ENOUGH TO PROVIDE AN INTERPRETATION OF THE PHYSICS.

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INTENDED USE

- ALLOW A DEVELOPER OF CB PROTECTIVE CLOTHING TO TEST THE IMPACT OF GARMENT OR MATERIAL DESIGNS WITHOUT THE EXPENSE OF CONSTRUCTING AND TESTING FABRICS.
- IDENTIFY THE LIMITING FACTORS IN MATERIAL OR GARMENT DESIGN TO POINT OUT THE POTENTIAL FOR IMPROVEMENT.

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MODEL REQUIREMENTS

- THE PHYSICS OF ALL SIGNIFICANT HEAT TRANSPORT MECHANISMS BE INCLUDED.
- PREDICTIONS OF HEAT TRANSPORT TO ABOUT 10% ACCURACY
- PREDICTION OF PHYSIOLOGICAL RESPONSE WELL ENOUGH TO
  - PREDICT IF HEAT STRESS WILL OCCUR.
  - GIVE THE CORRECT RELATIVE MAGNITUDE OF THE HEAT STRESS FOR DIFFERENT GARMENTS.
- INDEPENDENT DATA INPUT FOR ALL PHYSICAL AND PHYSIOLOGICAL PARAMETERS (NO FITTING OF THEORY TO DATA)

WHY ANOTHER MODEL?

- OTHER MODELS EXIST:
  - INTERNATIONAL STANDARDS ORGANIZATION (ISO) 7933 AND 8996.
  - UNITED STATES ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE (USARIEM) HEAT STRAIN MODEL.
  - STOLWIJK AND HARDY'S 25-NODE MODEL.
  - J.B. PIERCE LAB'S 2-NODE MODEL.
  - CAIN AND OSCZEVSKI'S (DREO) MODEL OF HEAT AND MOISTURE LOSS THROUGH NBC ENSEMBLES.
- NONE OF THE OTHER MODELS ENCOMPASS ALL HEAT TRANSPORT MECHANISMS EXPLICITLY.
- NONE START FROM MATERIAL PROPERTIES.

MODEL ASSUMES BODY CONSISTS OF SIX SEGMENTS (ALLOWS DIFFERENT AMOUNTS OF INSULATION)

BODY SEGMENT AREA	% OF BODY SURFACE
HEAD AND NECK	8
SHOULDERS AND TORSO	35
ARMS	12
HANDS	5
LEGS	33
FEET	7

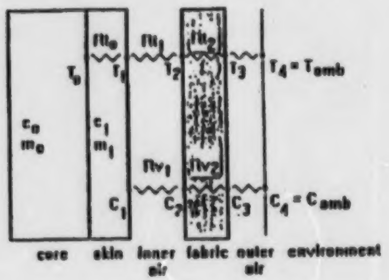
- HEAT TRANSFER BETWEEN SEGMENTS WILL BE IGNORED AS IT WILL BE ASSUMED TO BE NEGLIGIBLE.
- TWO LAYERS (MASS: 90% CORE - 10% SKIN)
- EQUATIONS FOR RATE OF HEAT STORAGE IN CORE AND SKIN LAYERS

- RATE OF HEAT STORAGE IN THE CORE IS EQUAL TO THE METABOLIC RATE, Q_{met}, LESS THE EXTERNAL WORK, W_{ext}, THE RESPIRATORY HEAT LOSS, Q_{res}, AND THE OVERALL HEAT TRANSFERS FROM THE CORE TO SKIN, Q_{core}:

$$m_o c_o \frac{dT_o}{dt} = Q_{met} - W_{ext} - Q_{res} - Q_{core} \qquad (1)$$

WHERE m_o IS MASS OF THE CORE (kg), c_o THE BODY'S HEAT CAPACITY (3.486 kJ·kg⁻¹·C⁻¹), T_o THE CORE TEMPERATURE (C) and t TIME (s)

SCHEMATIC OF THE PHYSICAL COMPONENT OF HEAT STRAIN MODEL



DRES

- Q_{core_j} (WATTS) ACROSS TISSUE LAYER BETWEEN CORE AND SKIN SURFACE OF EACH SEGMENT,

$$Q_{core_j} = \frac{T_0 - T_{1j}}{R_{T_0}} A_j \qquad (2)$$

WHERE T_0 IS THE CORE TEMPERATURE (ALL SEGMENTS EQUAL), T_{1j} THE SKIN TEMPERATURE OF SEGMENT, A_j SURFACE AREA OF THE jTH SEGMENT (m^2) AND R_{T_0} THE THERMAL RESISTANCE ($0.025\ m^2 \cdot K \cdot W^{-1}$ VASODILATED).

- DIFFERENT AMOUNTS OF INSULATION ON EACH SEGMENT -> DIFFERENT SEGMENTAL SKIN TEMPERATURES -> DIFFERENT RATES OF HEAT TRANSFER

DRES

- EACH SEGMENT IS AREA-WEIGHTED AND SUMMED TO PROVIDE OVERALL HEAT TRANSFER, QCORE,

$$Q_{core} = \sum_{j=0}^{5} \left(\frac{T_0 - T_{1j}}{R_{T_0}} \right) A_j \qquad (4)$$

- SUBSTITUTING -> 1ST ORDER DIFFERENTIAL Eq FOR RATE OF HEAT STORAGE IN THE CORE,

$$m_o c_o \frac{dT_0}{dt} = Q_{met} - W_{ext} - Q_{res} - \sum_{j=1}^{5} \frac{T_0 - T_{1j}}{R_{T_0}} A_j \qquad (5)$$

DRES

- USED PANDOLF FORMULA FOR METABOLIC RATE, Q_{met} FUNCTION OF BODY AND LOAD WEIGHT, WALKING SPEED, TERRAIN TYPE AND GRADE
- ASSUMED 10 - 25% OF METABOLIC RATE EXPENDED AS EXTERNAL WORK; THUS 75 - 90% OF METABOLIC RATE MUST BE DISSIPATED AS HEAT
- CAN MODEL WORK/REST CYCLES OF VARYING EFFICIENCY; USER SPECIFIES LIST OF ACTIVITIES AND THEIR DURATION

DRES

- MODEL USES DREO/DCIEM Eq FOR HEAT LOSS DUE TO RESPIRATION
  - ASSUMED THAT EXPIRED AIR SATURATED WITH WATER VAPOUR ($T_{ex} = T_0$) AND INSPIRED AIR AT RH ($T_{ins} = T_a$)
  - PREDICTION OF VENTILATION RATE (FUNCTION OF METABOLIC RATE)
    - ASSUMED PROTECTIVE RESPIRATOR DOES NOT AFFECT RESPIRATORY HEAT LOSS (PATTON *ET AL.*)
- USED FOURTNEY EQUATION TO PREDICT SWEAT RATE ($g \cdot s^{-1}$) AND EXPRESSED AS A SWEAT RATE PER UNIT AREA
  - ASSUMES: $T_0 \leq 37.2$ OR $T_1 \leq 34$ C , THEN NO SWEATING
  - ALL SEGMENTS SWEAT; DIFFERENT SKIN TEMPS -> DIFFERENT SWEAT RATES
  - ASSUMED MAX. SWEAT RATE OF 1.04 $L \cdot h^{-1}$ ($0.29\ g \cdot s^{-1}$) USARIEM USES 2.1 $ql \cdot h^{-1}$ ($0.56\ g \cdot s^{-1}$)

- RATE OF HEAT STORAGE (WATTS) IN A SEGMENT'S SKIN LAYER IS EQUAL TO HEAT TRANSFER TO SKIN FROM CORE, Q_{core_l}, LESS TOTAL DRY HEAT TRANSFER (CONDUCTIVE, RADIATIVE AND CONVECTIVE) AND EVAPORATIVE HEAT TRANSFER (SWEATING) FROM SKIN ACROSS THE AIR LAYER (BETWEEN SKIN AND FIRST FABRIC LAYER)

$$m_1c_1\frac{dT_{1l}}{dt}=\left(\frac{T_0-T_{1l}}{R_{T_0}}-\frac{T_{1l}-T_{2l}}{R_{T_{1l}}}-H_v\frac{C_{1l}-C_{2l}}{R_{V_{1l}}}\right) \qquad (10)$$

- TOTAL: 7 DIFFERENTIAL. EQUATIONS (6 FOR THE 6 SKIN LAYERS; 1 FOR CORE)

- FOR THE TRAPPED AIR LAYER

$$m_{2l}c_{2l}\frac{dT_{2l}}{dt}=\frac{T_{1l}-T_{2l}}{R_{T_{1l}}}-\frac{T_{2l}-T_{3l}}{R_{T_{2l}}}+Q_{c_{2l}} \qquad (11)$$

- HEAT FLOW IN AND OUT OF THE FABRIC LAYER (l= 3) IS,

$$m_{3l}c_{3l}\frac{dT_{3l}}{dt}=\frac{T_{2l}-T_{3l}}{R_{T_{2l}}}-\frac{T_{3l}-T_{4l}}{R_{T_{3l}}}+Q_{c_{3l}}+Q_{sol_l} \qquad (12)$$

SAME FORM EXCEPT FOR ADDED SOLAR RADIATION, Q_{sol}.

- SOLAR RADIATION IS ASSUMED TO TRANSFER HEAT TO THE OUTER SURFACE OF THE OUTERMOST FABRIC LAYER ONLY.
- AMBIENT TEMPERATURE IS ASSUMED TO BE CONSTANT FOR ALL SEGMENTS,

$$\frac{dT_{4l}}{dt}=0 \qquad (13)$$

- THIS SET OF DIFFERENTIAL EQUATIONS IS SOLVED USING THE RUNGE-KUTTA NUMERICAL TECHNIQUE.

- ASSUMING THREE FORMS OF WATER (LIQUID, VAPOUR, REGAIN) COME TO EQUILIBRIUM RAPIDLY, THE MAXIMUM AMOUNT OF WATER PRESENT AS VAPOUR OR REGAIN IS,

$$\dot{M}_{max}=C_sx(1-f)+\gamma M_f \qquad (14)$$

- M_{max} SERVES AS A COMPARATIVE CRITERION FOR DETERMINING THE HEAT RELEASED BY ABSORPTION AND CONDENSATION.
- IF $M>M_{max}$ THEN WATER MUST ACCUMULATE AS LIQUID BY CONDENSATION. THE HEAT RELEASED IS THEN GIVEN BY,

$$Q_c=H_v\frac{dM}{dt} \qquad (15)$$

- IF $M<M_{max}$ THEN WATER IS PARTLY VAPOUR; SOME IS ABSORBED

$$Q_c=H_a\frac{dM}{dt}\left(\frac{\gamma M_f}{x(1-f)C_s(T)+\gamma M_f}\right) \qquad (16)$$

- ASSUMED CLOTHING IS IN EQUILIBRIUM WITH ENVIRONMENT AT START.

- THERMAL RESISTANCE OF FABRIC IS PROPORTIONAL TO THICKNESS,

$$R_{T_l}=\frac{x_l}{k_l} \qquad (17)$$

- WHERE x_l IS THICKNESS (m), k_s IS THERMAL CONDUCTIVITY (0.04 W·m^{-1}·K^{-1})
- RADIATION TRAVELS UNIMPEDED ACROSS AIR THUS HEAT TRANSFER
- RADIATION TRAVELS UNIMPEDED ACROSS AIR THUS HEAT TRANSFER DEPENDS ON FAR INFRARED PROPERTIES OF SURFACES NEXT TO AIR LAYEF
- OVERALL THERMAL RESISTANCE OF AN AIR LAYER BETWEEN TWO FABRIC SURFACES COMBINES CONDUCTION, CONVECTION AND RADIATION,

$$R_{T_l}=1/h_c+\left(\frac{4\sigma T_m^3}{1/\varepsilon_l+1/\varepsilon_{l+1}-1}\right)^{-1} \qquad (18)$$

- WHERE σ IS STEFAN-BOLTZMANN CONSTANT (5.67X10^{-8} W·m^{-2}·K^{-4}), T_m IS MEAI TEMPERATURE (K), l & l+1 THERMAL EMMISSIVITIES OF SURFACES AND h_c DANIELSSON'S HEAT TRANSFER COEFFICIENT (W·m^{-2} K^{-1})
- FABRIC EMMISSIVITIES 0.85; SKIN 0.9; ENVIRONMENT 1.0

- DANIELSSON'S CONVECTION COEFFICIENT (INSIDE AND OUTSIDE CLOTHING):
  - NATURAL CONVECTION (NO WALKING OR WIND)
  - WALKING IN STILL AIR (NO WIND)
  - STANDING IN A WIND
  - WALKING IN A WIND
- OUTSIDE CLOTHING
  - CLOTHED INDIVIDUAL, $h_c = 3.6\ W{\cdot}m^{-2}{\cdot}K^{-1}$ (NATURAL)
  - CLOTHED INDIVIDUAL, $h_c = 10.2 v_v^{0.84}$ (WIND)
  - NUDE $h_c = 7.6 v_w^{0.40}$; CLOTHED $h_c = 7.2 v_w^{0.40}$ (WALKING)
  - WALKING IN THE WIND, $h_c = [(h_c(v_v))^x + (h_c(v_w))^x]^{1/x}$
  - WHOLE CLOTHED BODY, $x_{cl} = 2.4$; NUDE, $x_n = 1.5$

- INSIDE CLOTHING
  - AFFECTED BY FIT AND DESIGN OF GARMENT
  - MINIMUM WHOLE-BODY COEFFICIENT WAS $h_c = 2.0\ W{\cdot}m^{-2}{\cdot}K^{-1}$
  - APERTURES OF A LOOSE-FITTING ENSEMBLE OPEN, THE h_c VALUE WAS ALMOST UNCHANGED BY VIGOROUS ACTIVITY SUCH AS WALKING
  - APERTURES CLOSED, COEFFICIENT CHANGED BY ACTIVITY, $h_c = 8.5\ v_w^{0.45}$
  - USARIEM USES $h_c = 8.6\ v_v^{0.52}$

- TREATMENT OF SOLAR LOAD IS IN ACTUALITY QUITE COMPLEX AS IT IS COMPRISED OF THREE SOURCES: DIRECT, DIFFUSE AND REFLECTED.
- SIMPLIFIED BY APPLYING

$$Q_{sol} = \alpha A_j I_s \qquad (19)$$

WHERE α IS EMMISSIVITY OF OUTER CLOTHING, A_j SURFACE AREAS OF SEGMENT AND I_s IS RADIATION FLUX ($W{\cdot}m^{-2}$)

- PROVIDED FOUR MODES: CLEAR, PARTLY CLOUDY, CLOUDY, INDOORS (1000, 500, 250, AND 100 $W{\cdot}m^{-2}$)

- SIMILAR SET OF EQUATIONS FOR FLOW OF WATER VAPOUR
- MASS OF WATER PER UNIT AREA ON A SEGMENT'S SKIN SURFACE IS EQUAL TO THE MASS OF SWEAT PRODUCED (PER UNIT TIME, AREA), LESS THAT WHICH EVAPORATES FROM SKIN INTO THE FIRST CLOTHING LAYER

$$\frac{dM_{1j}}{dt} = m_{sw} - \frac{C_{1j} - C_{2j}}{R_{v_{1j}}} \qquad (20)$$

WHERE C_{1j} IS WATER VAPOUR CONCENTRATION AT THE SKIN, C_{2j} IS WATER VAPOUR CONCENTRATION IN NEXT LAYER ($g{\cdot}m^{-3}$) AND R_{v1j} IS WATER VAPOUR RESISTANCE ($s{\cdot}m^{-1}$)

$$\frac{dM_{2l}}{dt} = \frac{C_{1l} - C_{2l}}{R_{v_{1l}}} - \frac{C_{2l} - C_{3l}}{R_{v_{2l}}} \quad (21)$$

$$\frac{dM_{3l}}{dt} = \frac{C_{2l} - C_{3l}}{R_{v_{2l}}} - \frac{C_{3l} - C_{4l}}{R_{v_{3l}}} \quad (22)$$

$$\frac{dM_{4l}}{dt} = 0 \quad (23)$$

- MATERIAL'S RESISTANCE TO WATER VAPOUR DIFFUSION EASILY MEASURED
- IF AIR, VAPOUR RESISTANCE CAN BE APPROXIMATED BY

$$R_{vl} = \frac{x_l}{D_{air}} \quad (24)$$

WHERE x_l IS THICKNESS OF THE LAYER (m), D_{air} IS DIFFUSION CONSTANT, WATER THROUGH AIR ($m^2 \cdot s^{-1}$)

- C++ FOR WINDOWS; USER-FRIENDLY PULL-DOWN MENUS
- SOLVES SETS OF DIFFERENTIAL EQUATIONS USING RUNGE-KUTTA ROUTINE
- PRODUCES NEW SET OF M AND T EACH ITERATION (STEPSIZE 0.01 TO 0.001 SEC)
- PROGRAM CAN READ/WRITE TO INPUT/OUTPUT FILES

VALIDATION WITH PHYSIOLOGICAL DATA

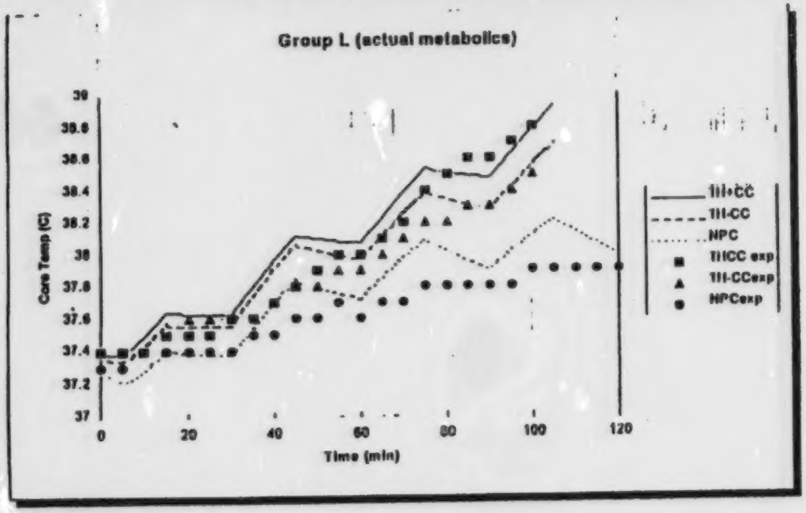
MCLELLAN ET AL (DCIEM 91-35)

CLOTHING	
TH + CC	CB ENSEMBLE IN TOPP-HIGH OVER UNDERWEAR AND COMBAT CLOTHING
TH - CC	CB ENSEMBLE IN TOPP-HIGH OVER UNDERWEAR
NPC CLOSE-FITTING	CB ENSEMBLE IN TOPP-HIGH OVER UNDERWEAR
WORK	
L	15 min @ 1.11 m·s^{-1} TREADMILL, 0% GRADE, 15 min REST
H	CONTINUOUS 1.33 m·s^{-1} TREADMILL, 3% GRADE

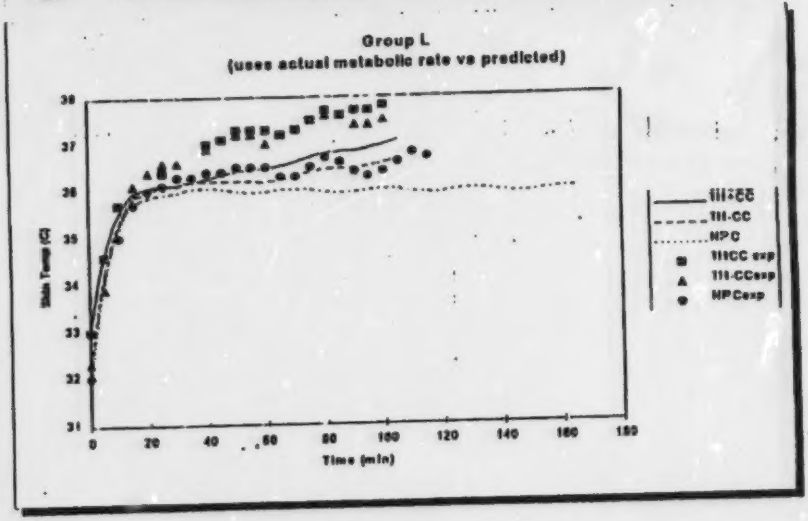
Environment

40°C, 25 - 30% RH, no wind

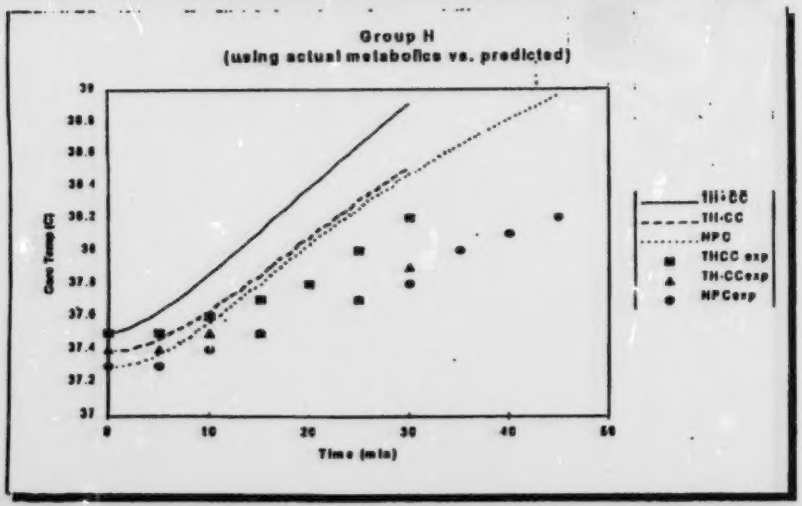
DRES


Group L (actual metabolics)

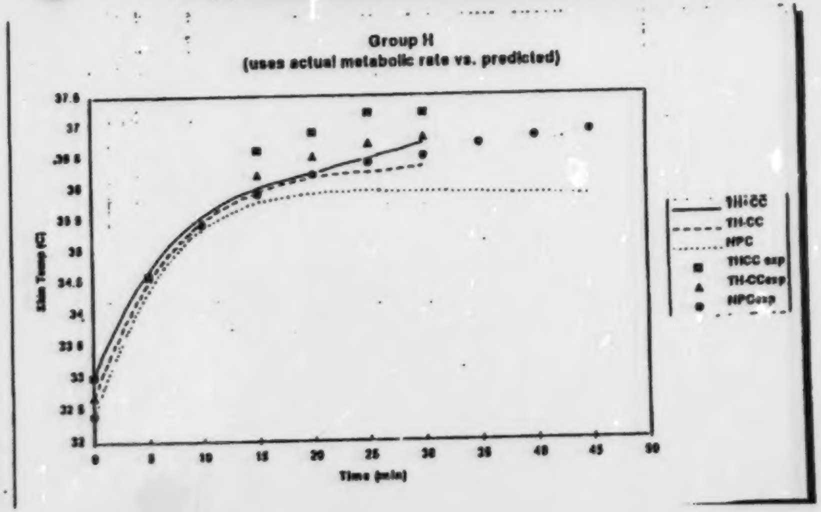
DRES


Group L
(uses actual metabolic rate vs predicted)

DRES


Group H
(using actual metabolics vs. predicted)

DRES


Group H
(uses actual metabolic rate vs. predicted)

VALIDATION WITH MANNEQUIN DATA

WINDSPEED ($m \cdot s^{-1}$)	USARIEM Mannequin (clo)	META Calculation (clo)
0.4	2.35	2.42
1.12	1.88	2.23
2.24	1.65	2.12

CANADIAN TOPP-HIGH ENSEMBLE.

SHORTCOMINGS OF MODEL

- CLOTHING
  - MOISTURE TRANSPORT BY VAPOUR DIFFUSION ONLY (LACKS WICKING AND DISSIPATION BY CONVECTION)
  - SIMPLE TREATMENT OF CONVECTION (NEED CONVECTION WITHIN FABRIC LAYERS AND WIND PENETRATION)
  - SIMPLE TREATMENT OF SOLAR LOAD (APPLIED EQUALLY TO ALL AREAS)
  - EFFECT OF GARMENT CLOSURES (CUFFS, ZIPPERS, HOODS)
  - EFFECTS OF APPLIED PRESSURE (WEBBING AND RUCKSACKS)
  - ESTIMATION OF AVERAGE THICKNESS OF AIR LAYERS WITHIN ENSEMBLE (FIT DEPENDENT)

SHORTCOMINGS OF MODEL

- PHYSIOLOGY
  - MANY SIMPLIFICATIONS AND ASSUMPTIONS
  - METABOLIC RATE, WORK EFFICIENCY, SWEAT RATE HAVE LARGE EFFECT ON MODEL PREDICTIONS
  - WORK/REST CYCLES PRODUCE A STEP FUNCTION FOR METABOLIC RATE (INSTANTANEOUS CHANGE RATHER THAN DECAY OR GRADUAL ONSET)
  - MARRIAGE OF CLOTHING AND HUMAN PHYSIOLOGY MAKES VALIDATION DIFFICULT
  - IGNORES INTERCOMPARTMENTAL HEAT EXCHANGE
  - IGNORES POSTURAL EFFECTS

SHORTCOMINGS OF MODEL

- COMPUTING
  - RUNS SLOW ON 486
  - IMPLEMENT AN ADAPTIVE STEP SIZE NUMERICAL SOLUTION (PREDICTOR-CORRECTOR METHOD VS. RUNGE-KUTTA)
  - NEEDS BETTER GRAPHICS
  - TEDIOUS TO ENTER INPUT PARAMETERS AND PROCESS OUTPUT FILES
  - IMPLEMENT HELP

NEXT PHASE OF MODELLING

- SUPPORT COMMITMENTS TO TTCP SUBGROUP ETP-11
- CALCULATE THERMAL INSULATION AND WATER VAPOUR PERMEABILITY OF NBC ENSEMBLES
- ENHANCE DRES HEAT STRAIN MODELLING STUDIES
- EXPERIMENTAL STUDY OF MOISTURE TRANSFER THROUGH MULTI-LAYERED FABRIC SYSTEMS

APPROACH

- SEPARATE CLOTHING AND PHYSIOLOGICAL MODEL
- COMPARE CLOTHING MODEL TO SWEATING HOT PLATE EXPERIMENTS
- DERIVE EQUATIONS FOR LIQUID TRANSPORT FROM EXPERIMENTAL DATA
- RECOMBINE CLOTHING MODEL WITH PHYSIOLOGICAL MODEL
- VALIDATE RECOMBINED MODEL TO ADDITIONAL DCIEM EXPERIMENTS

EXPERIMENTAL PROTOCOL

- CONDUCT SWEATING HOT PLATE EXPERIMENTS ON CURRENT & FUTURE CF CB MATERIALS.
- MEASURE MASS OF WATER IN EACH LAYER WHILE COLLECTING THERMAL DATA FROM SWEATING HOT PLATE.
- DIFFERENT AMBIENT WATER VAPOUR CONCENTRATIONS:

10°C and 51.6% RH	->	4.8 $g \cdot m^{-3}$
20°C and 54.4% RH	->	9.4 $g \cdot m^{-3}$
30°C and 57.0% RH	->	17.3 $g \cdot m^{-3}$
40°C and 59.4% RH	->	30.3 $g \cdot m^{-3}$

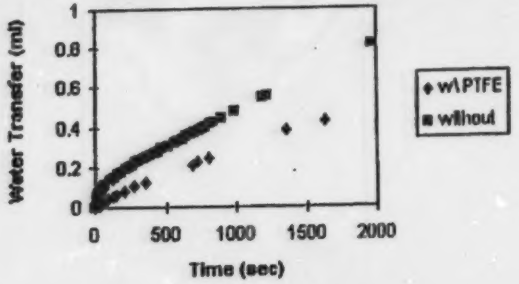
- VARY SWEAT RATE: 180, 360 and 540 $g \cdot m^{-2} \cdot h^{-1}$.

EXPERIMENTAL PROTOCOL

- VARY THICKNESS OF AIR LAYERS BETWEEN FABRICS
- FOR DIRECT CONTACT BETWEEN FABRIC AND PLATE ALLOW:
  - LIQUID AND VAPOUR TRANSPORT
  - VAPOUR ONLY (PTFE BARRIER)
  - NEITHER LIQUID OR VAPOUR (PE BARRIER)
- APPLY EXTERNAL PRESSURE (LOAD CARRIAGE, KNEELING, SITTING...)
- ORIENTATION WITH RESPECT TO GRAVITY.

EXAMPLE OF VAPOUR AND VAPOUR/LIQUID TRANSPORT INTO CF NBC IPE FABRIC

- WHEN FABRIC IS IN CONTACT WITH A SOURCE OF LIQUID, THE TOTAL WATER TRANSPORT INCREASES SIGNIFICANTLY



- AN EXAMPLE OF CURRENT CF CW COVERALL
  - 30 MINUTES OF SWEATING AT 540 g/m²/h @ 20 °C & 54.4% RH
  - INTIMATE CONTACT OF LAYERS (NO INTERMEDIATE AIR LAYERS); NO EXTERNAL PRESSURE
    - (1) DETERMINE AREA BETWEEN EVAPORATIVE HEAT LOSS AND DRY BASELINE
    - U_{evap} = 137.03 kJ/m² WAS MEASURED
    - (2) USE WATER MASS DATA TO DETERMINE ACTUAL MASS THAT EVAPORATED:

$$M_{evap} = M_{delivered} - M_{remaining}$$

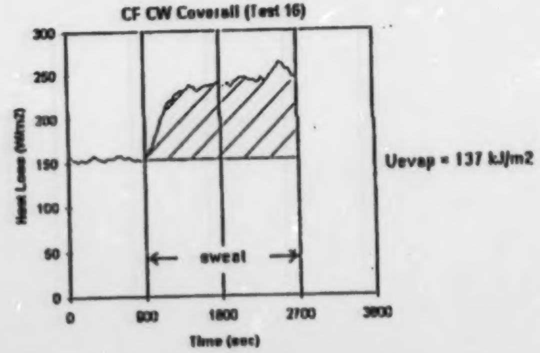
$$= 5.217 - 2.986\ \text{g} = 2.231\ \text{g EVAPORATED}$$

- AN EXAMPLE OF CURRENT CF CW COVERALL
    - (3) IF ALL SWEAT PRODUCED AT SKIN *EVAPORATED AT SKIN*, THEORY SAYS:

$$U_{evap} = L_v * M_{evap} = (2411\ \text{J/g} * 2.231\ \text{g})/0.02\ \text{m}^2$$

- THUS 268.95 kJ/m² SHOULD BE EXTRACTED NOT 137.03 kJ/m²
  EFFICIENCY = (137.03/268.95) = 50.9%
- OUR MODEL (AND OTHERS) ASSUME ALL WATER EVAPORATES AT SKIN (100% EFFICIENCY)

SWEATING HOT PLATE EXPERIMENT: AN EXAMPLE OF FABRIC FROM THE CURRENT CF NBC IPE (30 min SWEAT AT 540 g/m²/h)



- DETERMINATION OF MAXIMUM AIR LAYER THICKNESS IN CURRENT CF CW COVERALL
  - INFLATE STRETCHABLE MANNEQUIN INSIDE REG. MED. SUIT
  - MEASURE CIRCUMFERENCES @ ANKLE, KNEE, THIGH, WRIST, HEAD AND WAIST
  - ASSUME CIRCULAR; DETERMINE MAXIMUM RADIUS
  - CIRCUMFERENCES OF 50TH PERCENTILE MALE/FEMALE US ARMY (1988 ANTHROPOMETRIC SURVEY), DETERMINE MAX. RADIUS
  - DIFFERENCES IN RADII -> AVERAGE SPACE BETWEEN SKIN-COVERALL
  - MALE AVERAGE: 46 ± 14 MM
  - FEMALE AVERAGE: 52 ± 14 MM

Wargaming and Analysis in Support of Integrated Protective Clothing and Equipment Projects

Lisa Willner

Department of National Defence

IPCE
Wargaming and Analysis

- Aim
- Methodology
- Measures of Effectiveness
- Schedule

Aim

- Effectiveness of systems being considered
- Synergism
- Cost-benefits analysis
- IPCE and IPCE-TD

Methodology

- Wargaming and other analytical tools
- Compare 1998 soldier with IPCE soldier in 2010 conflict
- Infantry company on defensive and infantry company on offensive
- DOR (J &L) and DCIEM

Measures of Effectiveness

- High level - operations
- Mid level - capability based
- Low level - clothing and equipment based

High Level MOEs

- Was mission successful?
- How long did it take?
- How many lives were lost? - relative value
- What other resources were expended?

Mid Level MOEs

- Lethality
- Survivability
- Sustainability
- Mobility
- C3I
- Human Performance

Low Level MOEs

- Based on clothing and equipment
- Consider possible positive and negative impacts
- Related to mid level MOEs
- e.g. helmet, personal radio

Difficult Areas to Model

- Communication - especially different degrees of ability to communicate
- Effects of fatigue, etc.
- Effects of loss of batteries
- Situation awareness

Cost-Benefits Analysis

- High, mid, and low expense systems
- Estimated costs for 2005-2010

Schedule

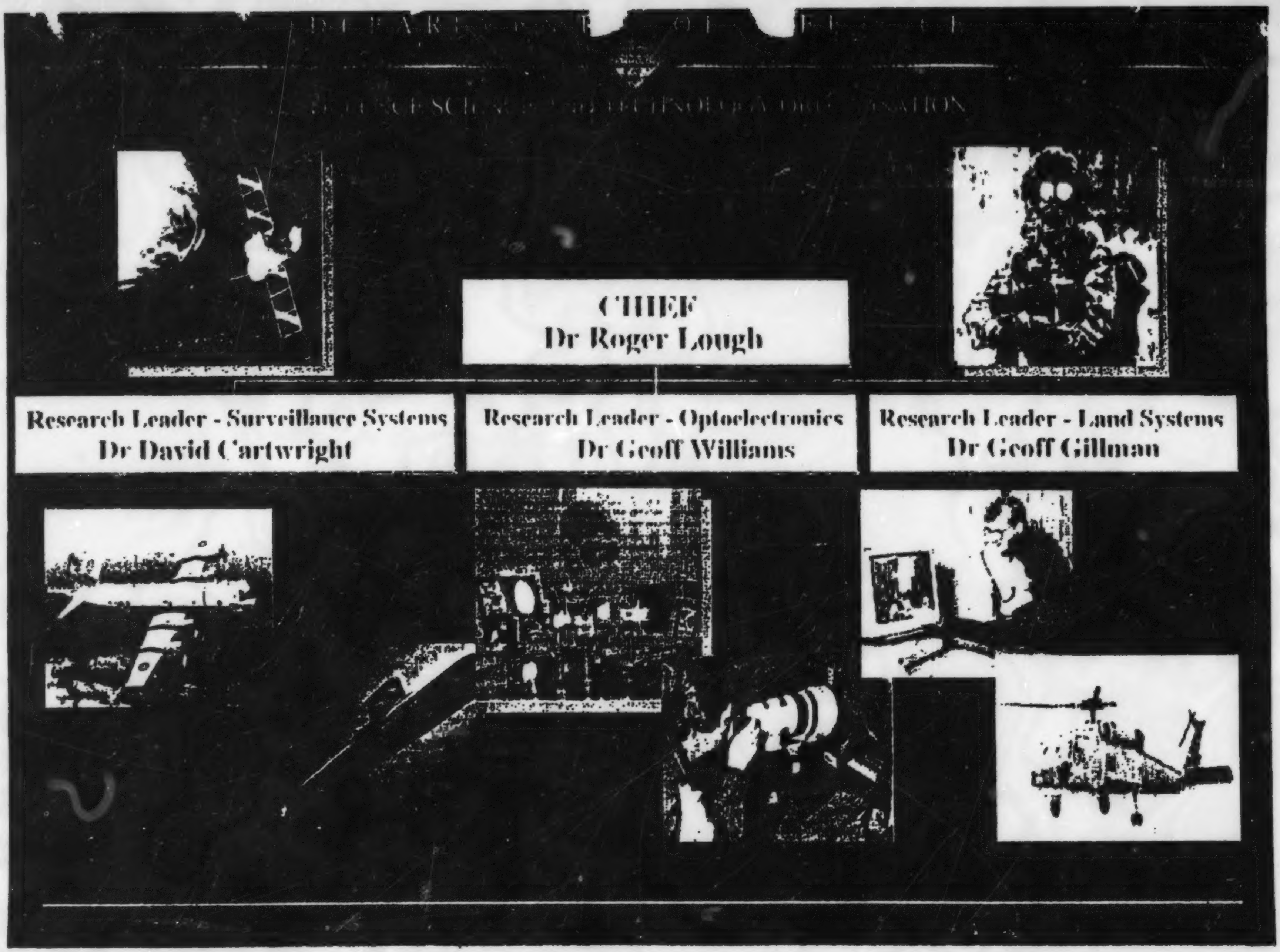
- Workshop 27-31 January 1997
- Start analysis - February 1997
- Phase 1 report - June 1997
- Further analysis

ANNEX H
DOR(J&L) RN 9812
July 1998

Soldier Combat System Studies

John Coleby

Head, Operational Analysis



DEPARTMENT OF DEFENCE

DEFENCE SCIENCE AND TECHNOLOGY ORGANISATION

CHIEF
Dr Roger Lough

Research Leader - Surveillance Systems
Dr David Cartwright

Research Leader - Optoelectronics
Dr Geoff Williams

Research Leader - Land Systems
Dr Geoff Gillman

Aim: to optimise the capability of
the combat unit as an effective
integrated system

Project WUNDURRA

- Goal introduction is post 2000
- Integrated - look at the Soldier Combat System
- Evolutionary - not a single buy
- “Appropriate” technology - not necessarily “high” technology
- Doctrine important
- Will fit in with Army 21
- Currently in formative stages

- Application of S&T to increase the effectiveness of the infantry soldier post 2000
- Force Development (Land) Program, started Nov 94 with authorisation for Phase1

Phase 1	94-96	Analysis Phase
Phase 2	95-98	Capability Development
Phase 3	99-10	Phased Acquisition

- Strong (selective) links to O/S Programs

Current Status

- Concepts and options formulation through integration of:
  - Army 21 requirements
  - Army combat unit insights
  - combat support requirements
  - front end analysis

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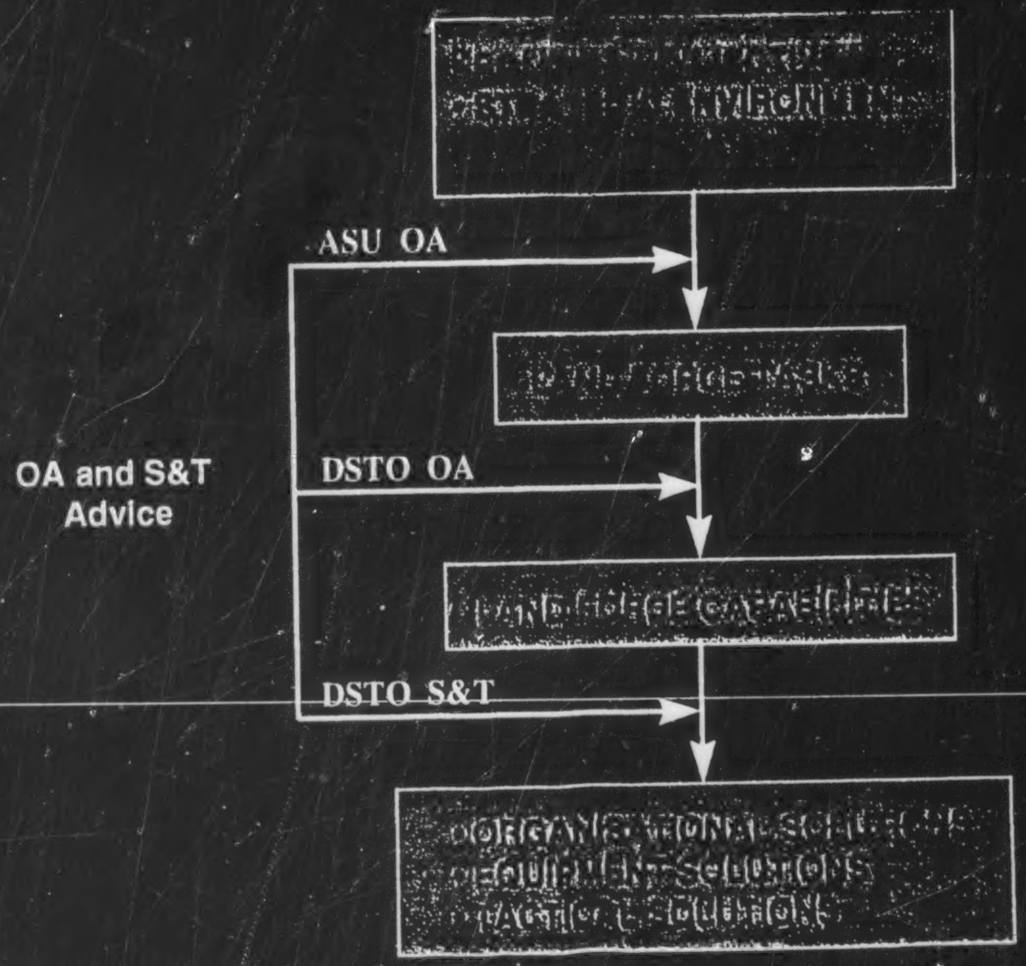
ADF Determination of CAPABILITIES



[illegible]
STRATEGIC ENVIRONMENT

LAND FORCE TASKS

LAND FORCE CAPABILITIES

ORGANISATIONAL SOLUTIONS
EQUIPMENT SOLUTIONS
TACTICAL SOLUTIONS

OA and S&T
Advice

ASU OA

DSTO OA

DSTO S&T

Land, Space & Optoelectronics Division

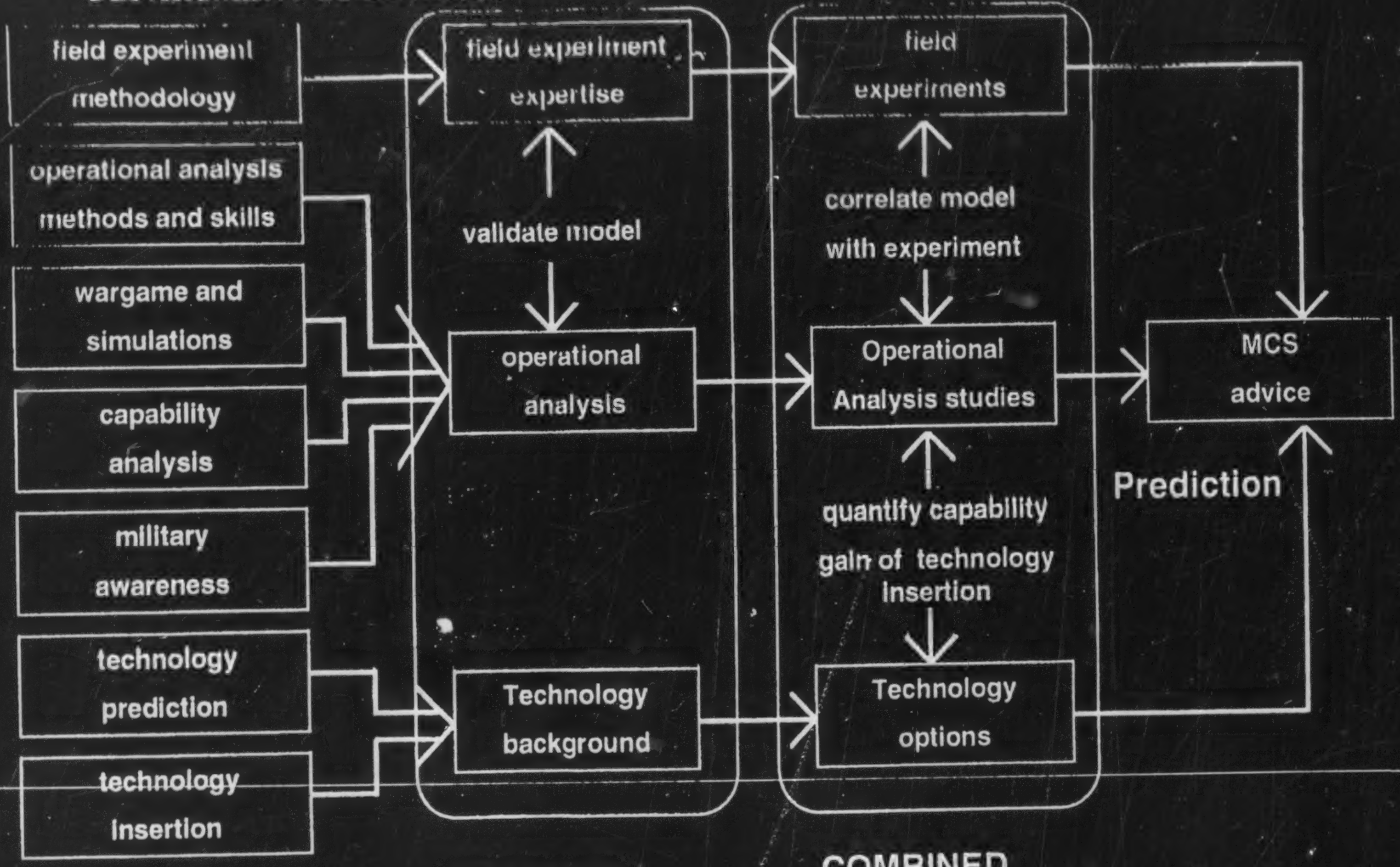
DSTO
AUSTRALIA

[illegible] enabling research

[illegible] with relevant overseas programs

LAND, SPACE & OPTOELECTRONICS DIVISION DSTO

DEPARTMENT OF DEFENCE


field experiment methodology
operational analysis methods and skills
wargame and simulations
capability analysis
military awareness
technology prediction
technology insertion
field experiment expertise
validate model
operational analysis
Technology background
field experiments
correlate model with experiment
Operational Analysis studies
quantify capability gain of technology insertion
Technology options
MCS advice
Prediction

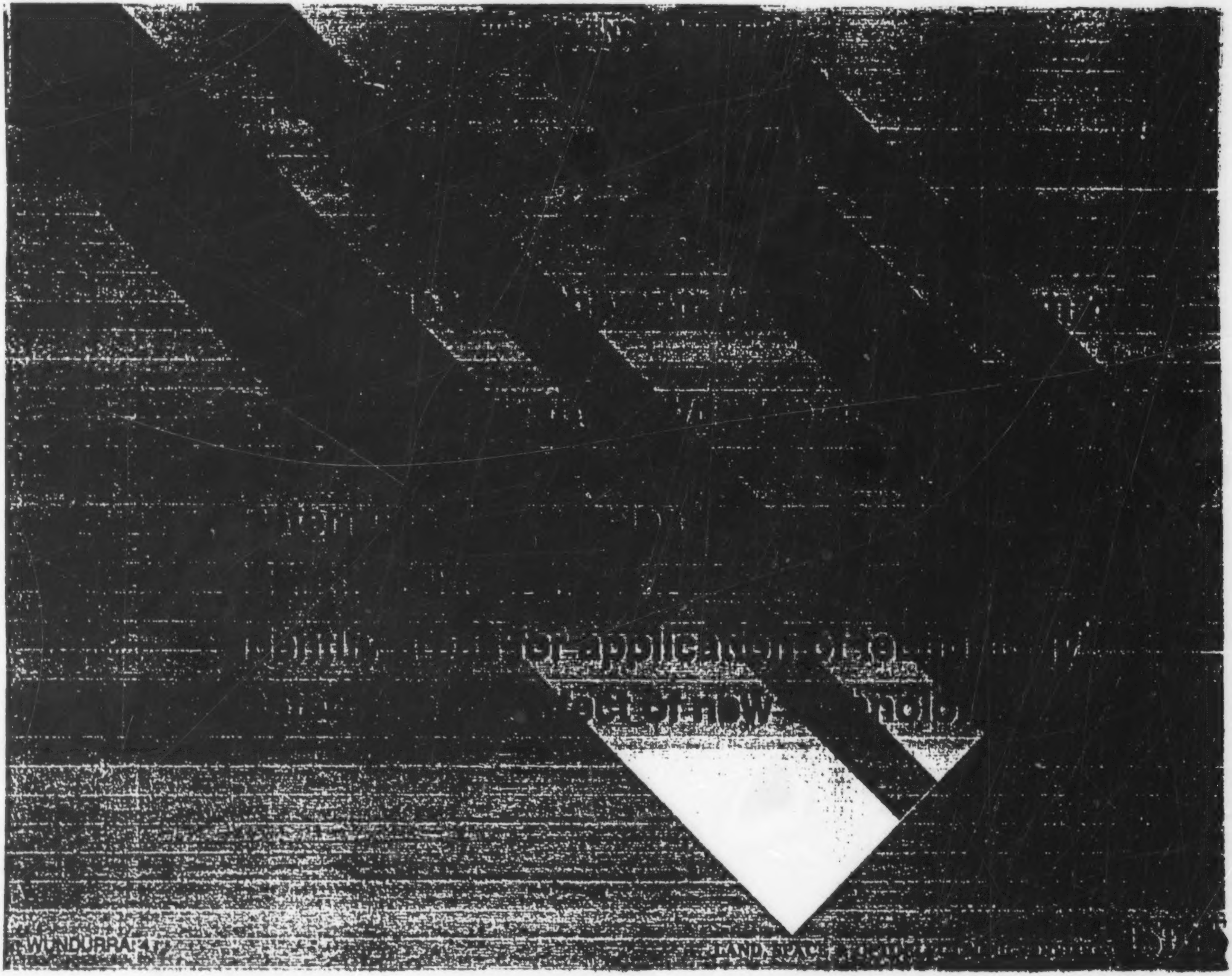
SUBACTIVITIES

ENABLING OBJECTIVE

COMBINED APPLICATION OBJECTIVE

Land, Space & Optoelectronics Division

DSTO AUSTRALIA

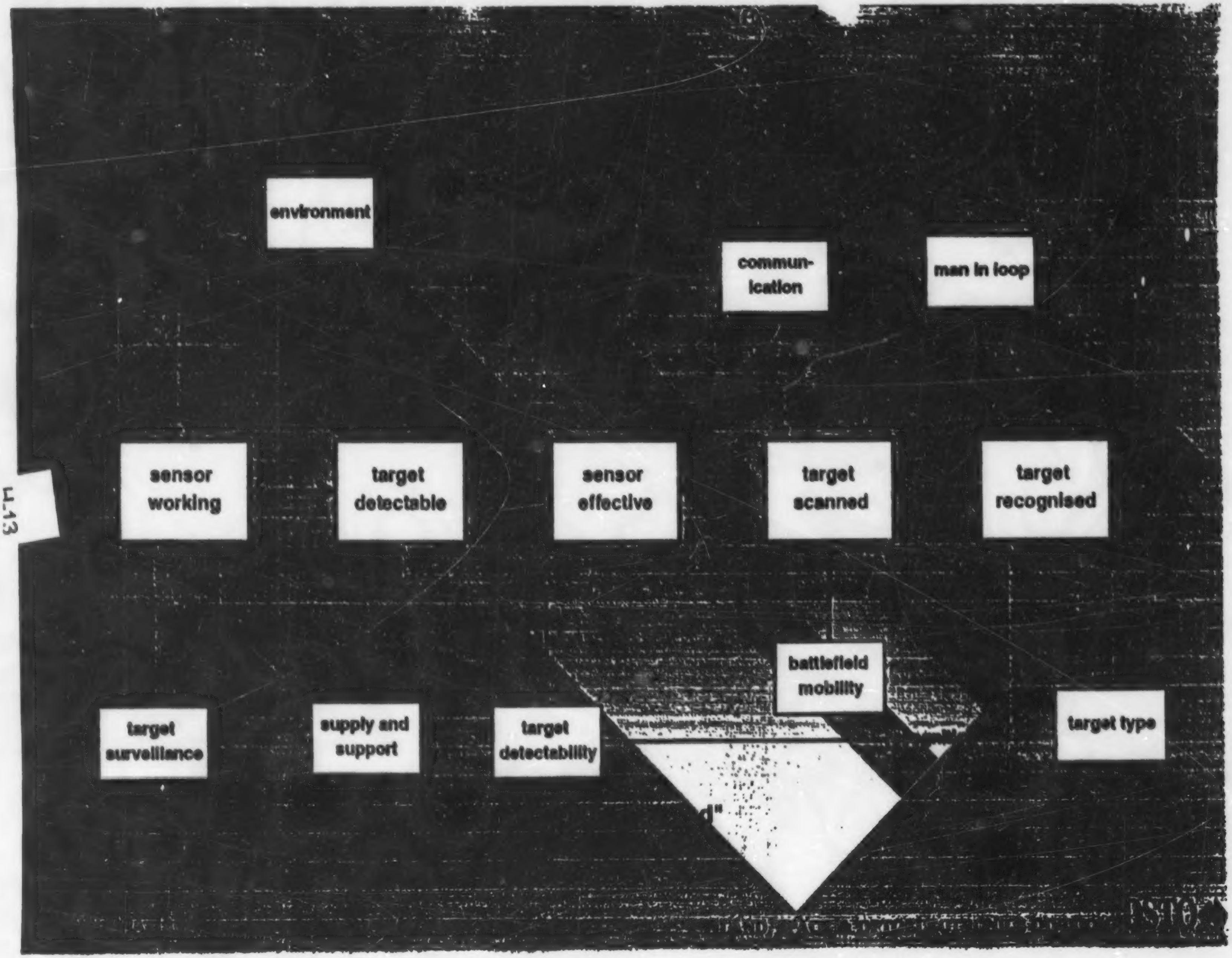


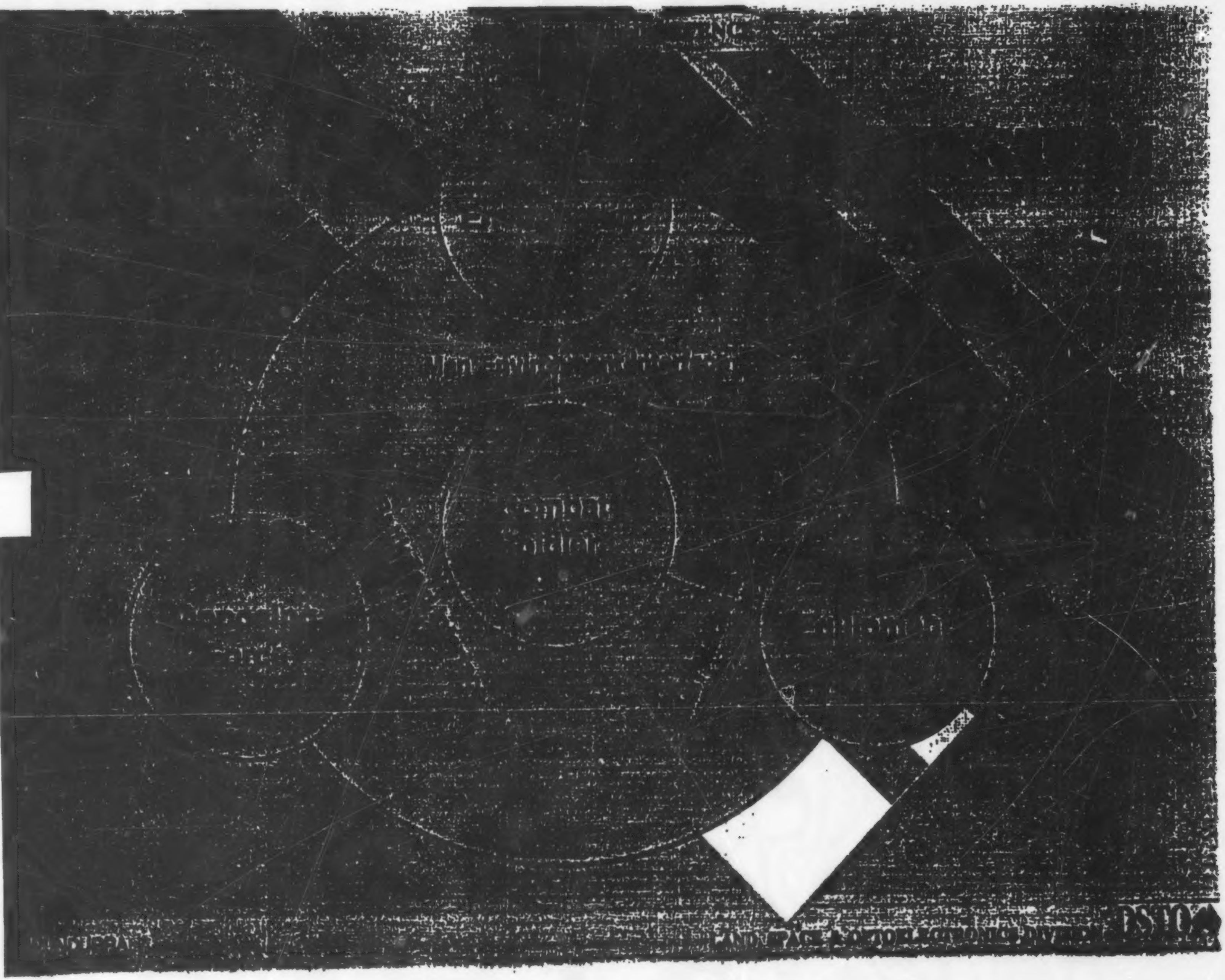
of application of ge
act of new
nolo
WUNDURRA
LAND SPACE

- [illegible] environment
- Low level conflict

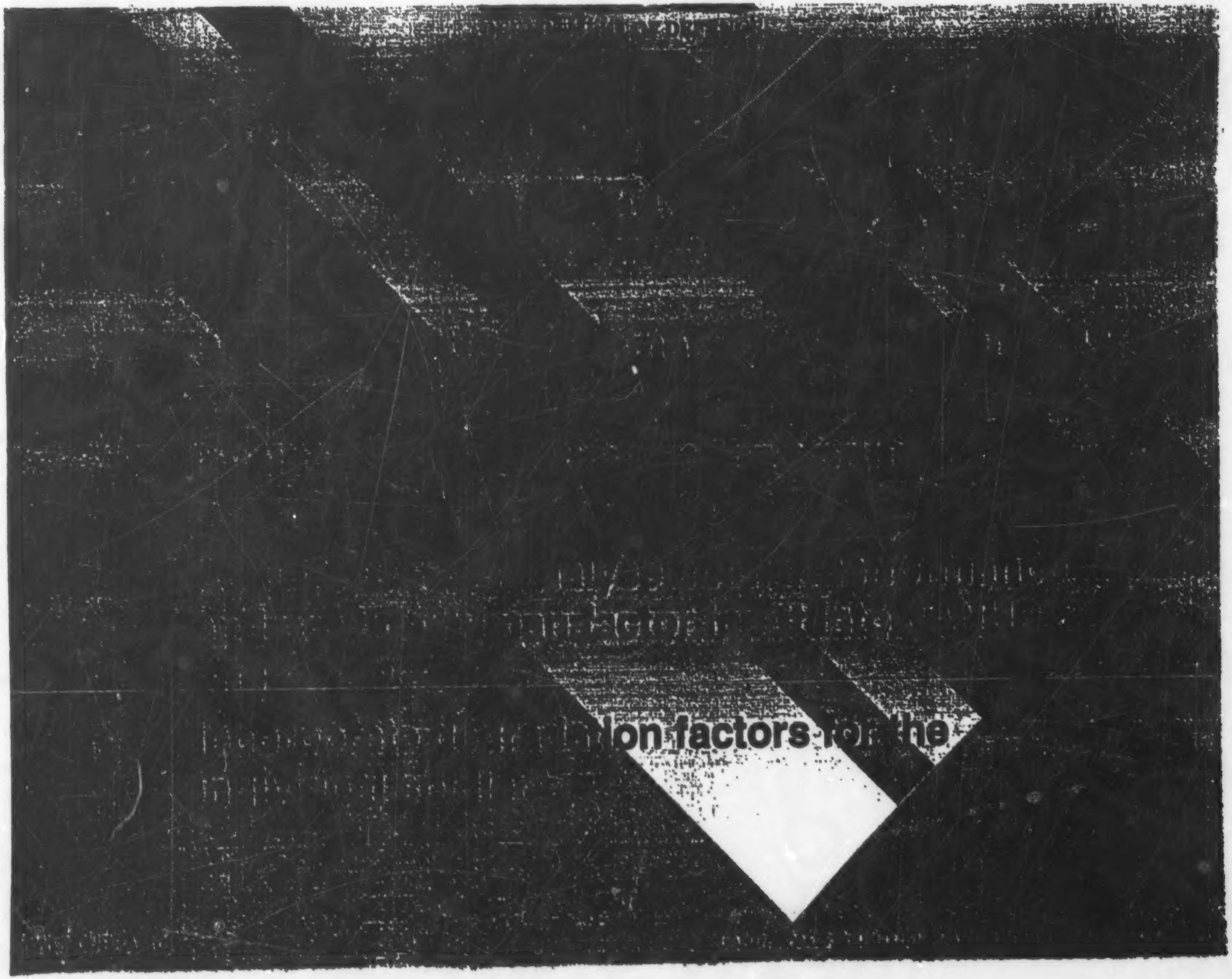
WUNDURRA-5

LAND, SPACE & OPTOELECTRONICS DIVISION DSTO


environment
commun-
ication
man in loop
sensor working
target detectable
sensor effective
target scanned
target recognised
battlefield mobility
target surveillance
supply and support
target detectability
target type


DSTO

games and simula
lerations es



ion factors for the

- Strength
- Heat stress
- Vigilance
- Information overload
- Fatigue
- Combat stress
- K95 & Soldier's Day

Computer Simulation of Human Performance

- Soldier movement
- Seeing
- Stress and Morale

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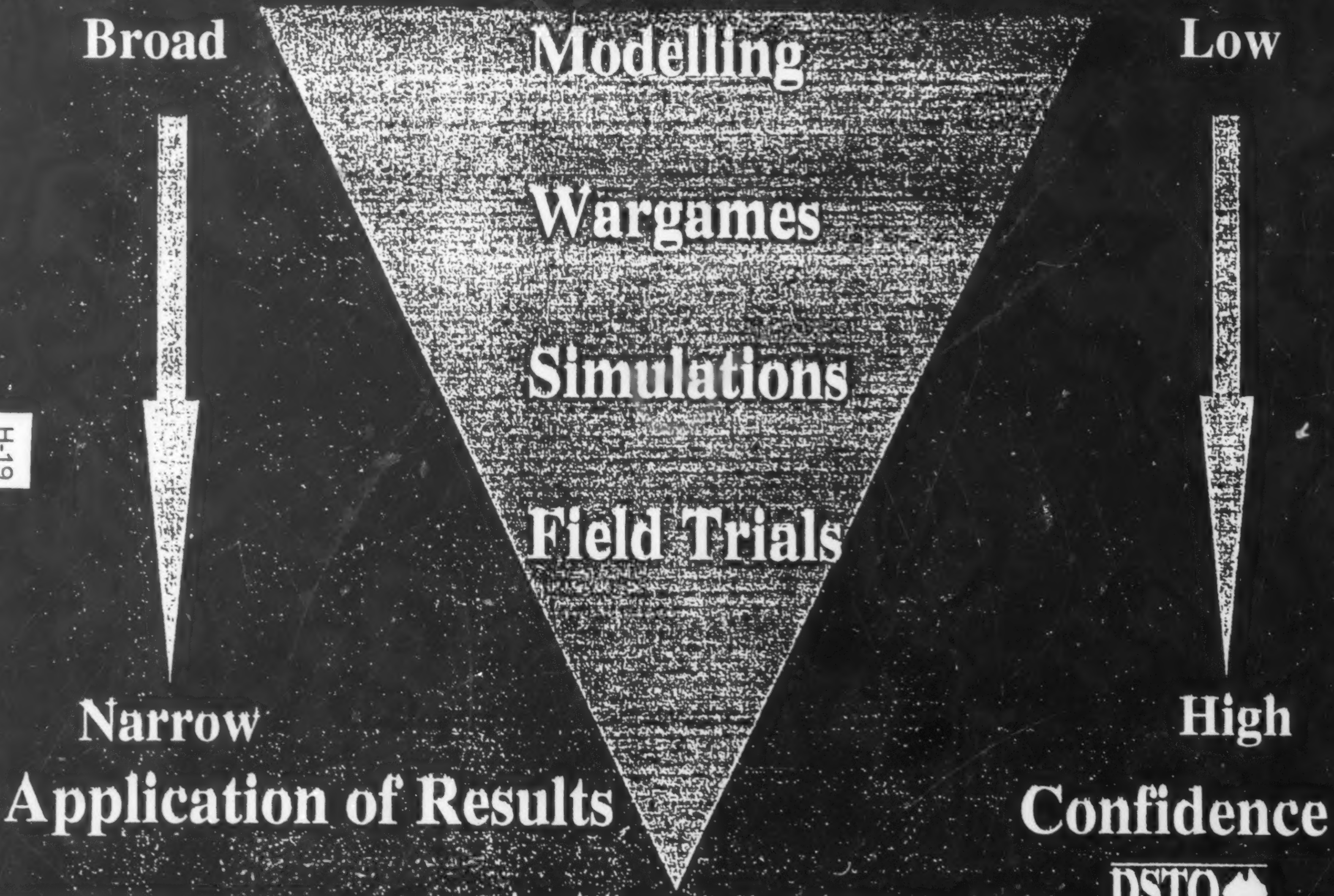

Broad

Narrow

Application of Results

Modelling

Wargames

Simulations

Field Trials

Low

High

Confidence

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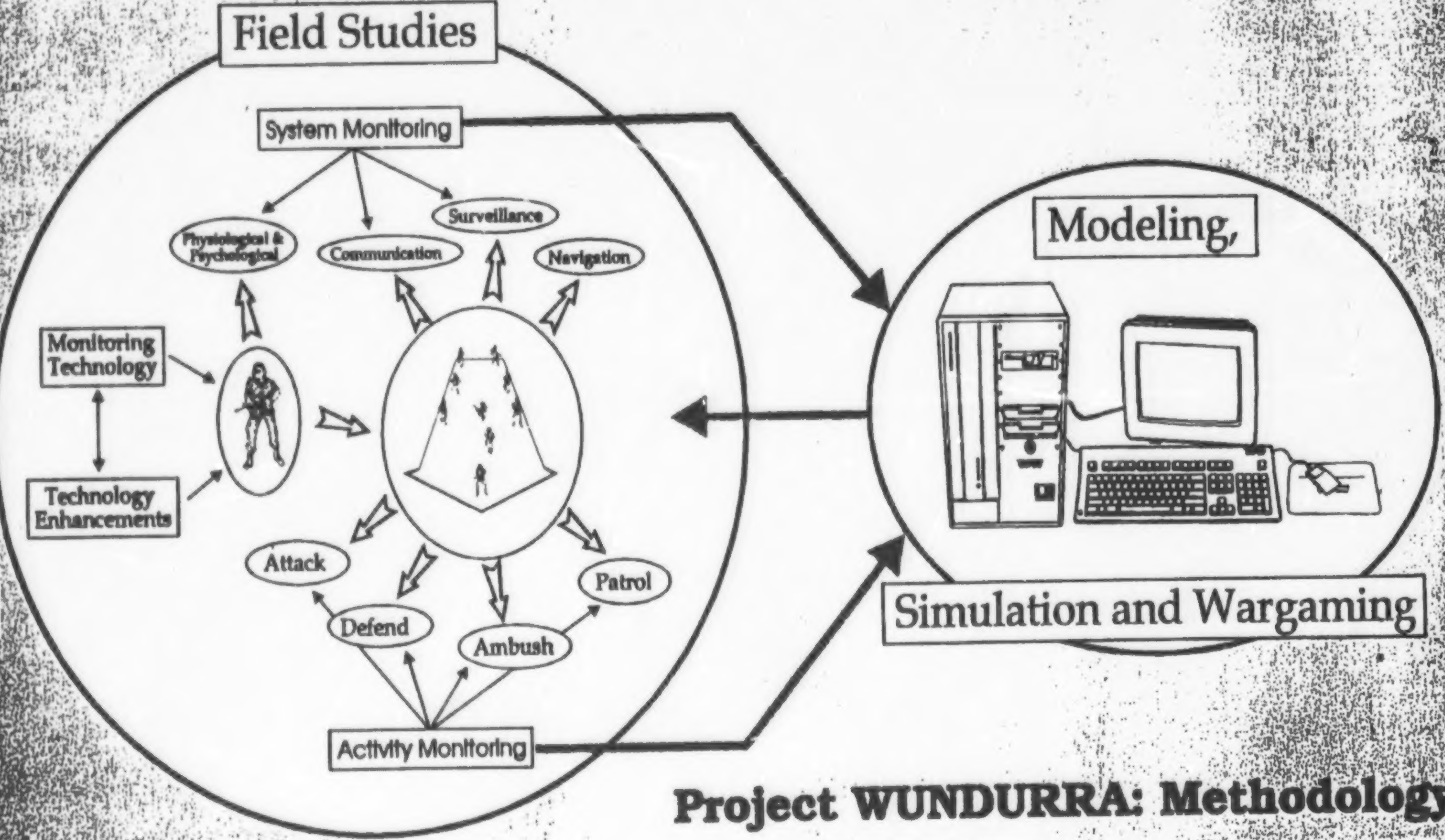
Outline Approach

Model	Test	Model
Define Experimental Regime Identify Critical Areas Propose Hypothesis	Model Validation Test Model Deficiencies Confirm Hypothesis	Prediction Model Refinement

Project WUNDURRA: Methodology


Field Studies
System Monitoring
Physiological & Psychological
Communication
Surveillance
Navigation
Monitoring Technology
Technology Enhancements
Attack
Defend
Ambush
Patrol
Activity Monitoring
Modeling,
Simulation and Wargaming

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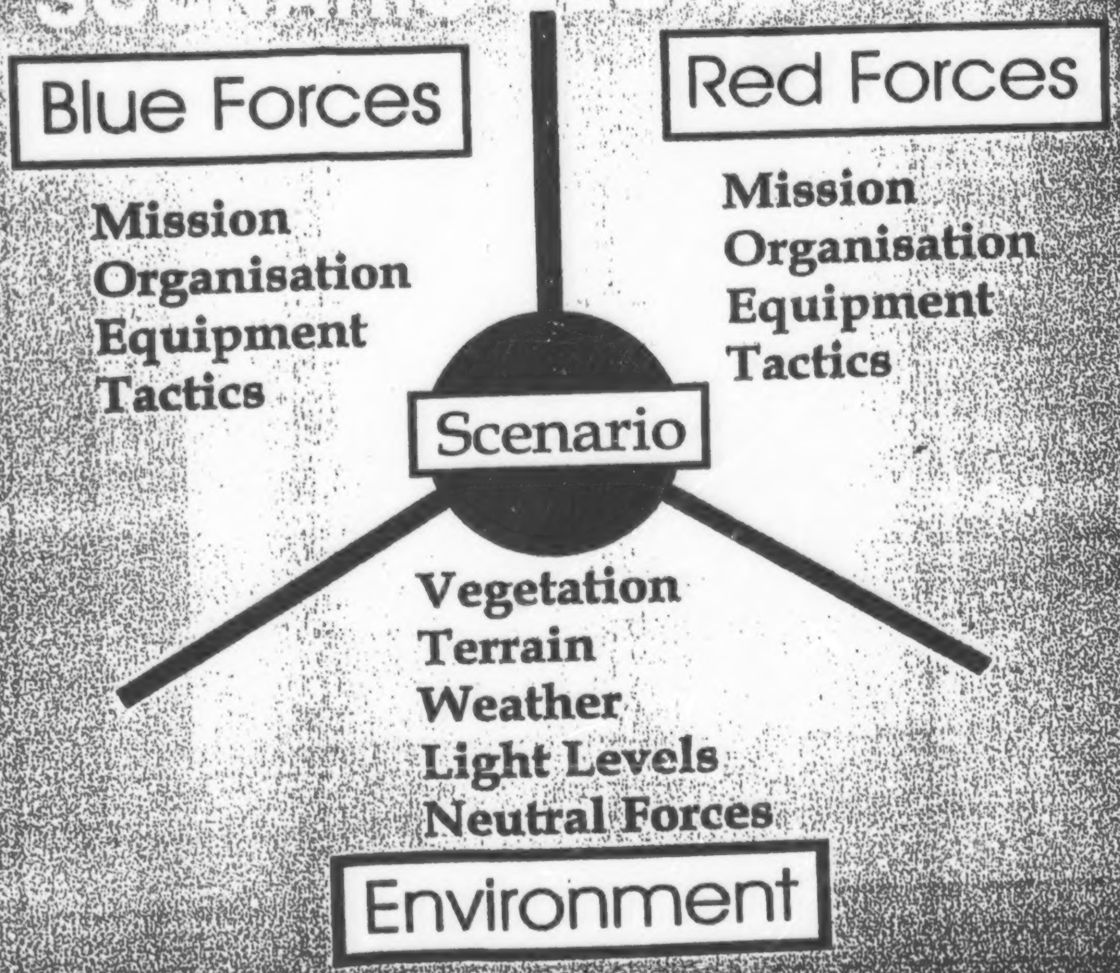
SCENARIO ELEMENTS



Blue Forces

- Mission
- Organisation
- Equipment
- Tactics

Red Forces

- Mission
- Organisation
- Equipment
- Tactics

Scenario

- Vegetation
- Terrain
- Weather
- Light Levels
- Neutral Forces

Environment

DSTO

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- Reactive Patrol (including quick attack)
  - Night/Day Observation Post
    - Night Ambush

All three scenarios were conducted by Low, Medium and High Tech sections.

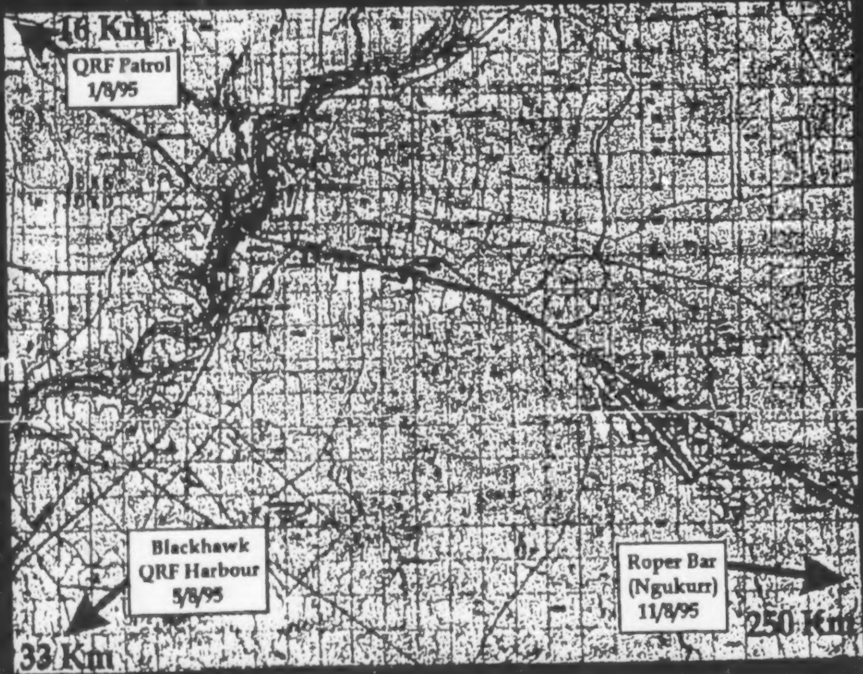
Field Study Analysis

Classification of activities for analysis

Movement Rates
Patrol Routes

Load Weight and Composition
Heart Rate

Temperature and RH (RSI)
Vegetation and Going


16 Km
QRF Patrol
1/8/95
Blackhawk
QRF Harbour
5/8/95
33 Km
Roper Bar
(Ngukurr)
11/8/95
250 Km

- Commanders Hand Held Data Terminal (CHHDT) *(Mid and High Tech)*
  - Digital Map
  - GPS
- Intrasection Communications *(Mid and High Tech)*
- Night Fighting Equipment *(High Tech Only)*
  - Night Vision Goggles
  - Night Aiming Devices

- Activities
  - Military Observers/Evaluators
  - Video
  - Interviews
- GPS data
  - Movement rates
  - Patrol Routes
- Environmental Data
  - Video/still photography
  - Temperature/Relative Humidity Probes

Monitoring Techniques (Cont.)

- Individual Weapon Effects Simulation System (IWESS)
  - Ammunition usage
  - hits/misses
- Communications Monitoring
  - Platoon Net (Speech Time Recorders and Log Book)
  - Section Net (Voice activated recorders)
  - Observers (watching for field signals etc.)
- Physiological Monitoring

Preliminary Observations/Results

- Essential base line data obtained for developing a methodology to compare the performance of standard and technologically enhanced sections.
- Synergistic effects observed that may not have been identified using computer simulations alone.
- Some useful data obtained for input into models.
- Exposure of Civilian Analysts to Army

Analysis of Results

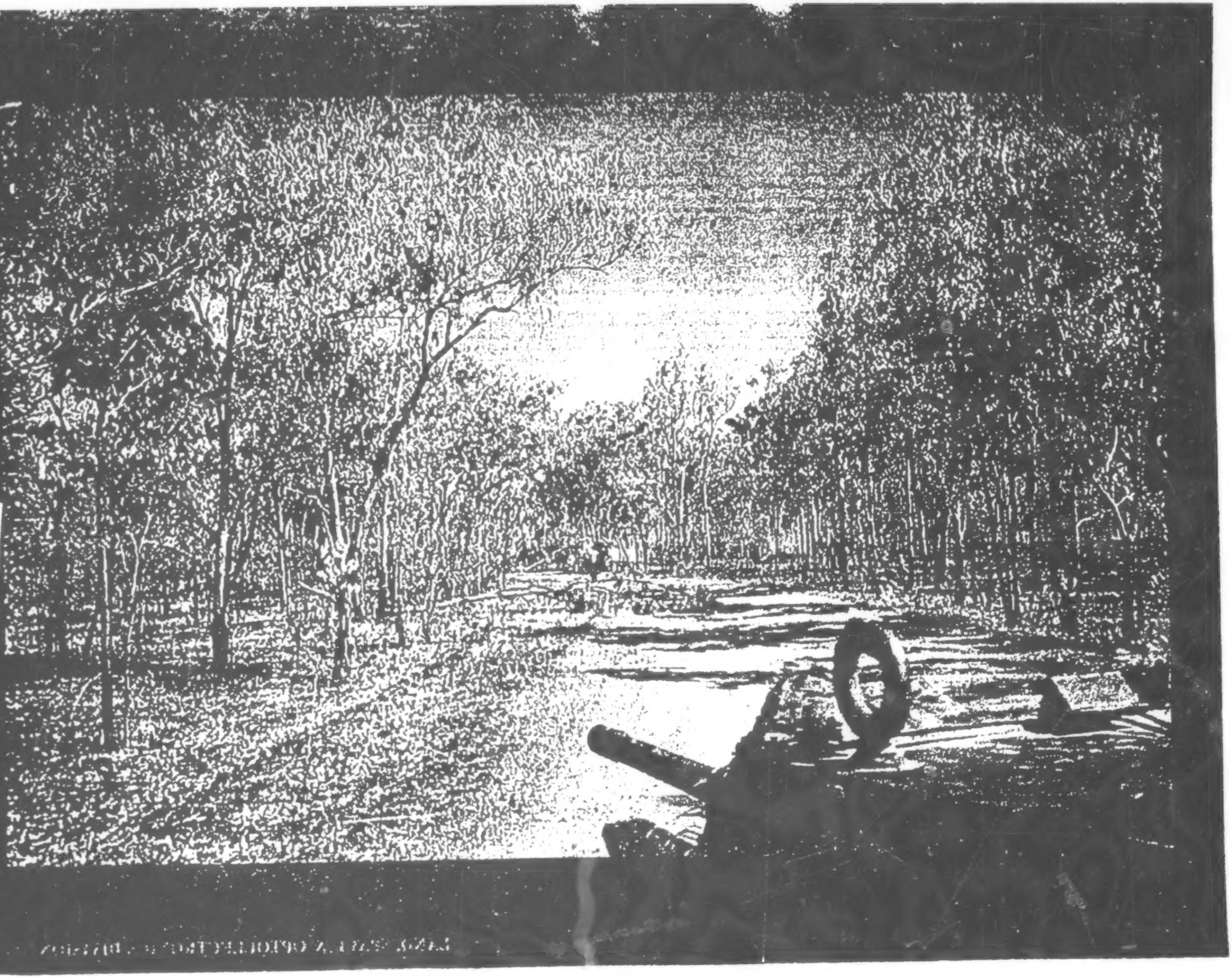
- Measures of Capability
  - ability to conduct high level tasks
- Measures of Outcome
  - mission sucess
- Measures of Effectiveness
  - coverage areas, loss exchange ratio
- Measures of Performance
  - detection ranges, accuracy

Future Field Trials

SCSES Singleton 14 APR - 16 MAY '97
and TLG-8 Study OCT '97.

Objectives

- Verify data collection methodology
- Collect data on ‘part tasks’ for verification of combat models, simulations and Wargames.



H-31

Objective of FP Soldier Modernization

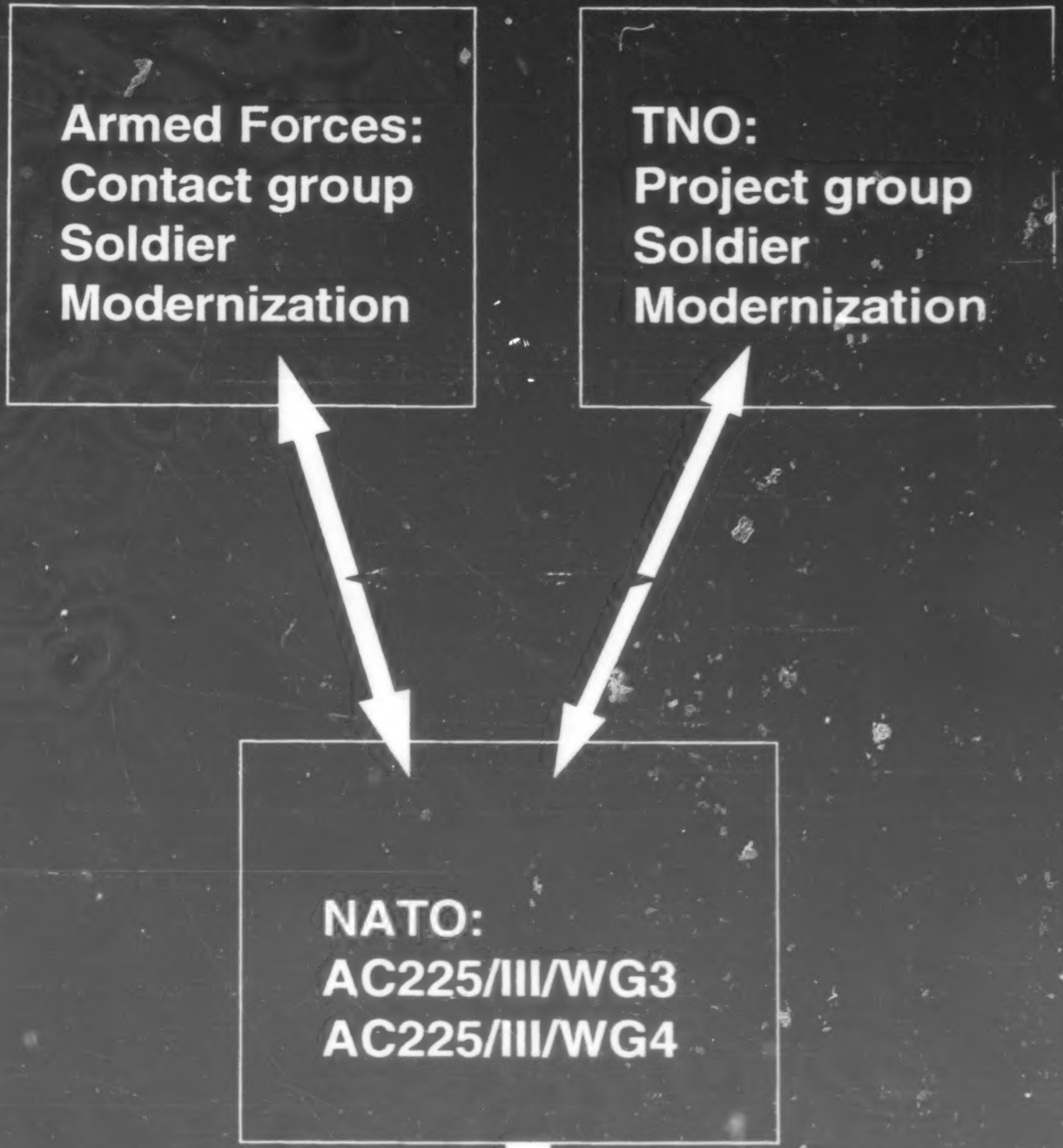
To increase the effectiveness of the Dutch Soldier by means of developing an integrated, modular built Soldier System

- Lethality
- Survivability
- Command and control
- Mobility
- Sustainment

Definition of Focus Programme

A *Focus Programme* is a set of projects with a common operational goal, based on a systematic and integral evaluation of probable operational scenario's and technical solutions to define in a step wise fashion with increasing accuracy the requirements according to the Defense Material Planning process

Organization FP SM



Armed Forces:
Contact group
Soldier
Modernization

TNO:
Project group
Soldier
Modernization

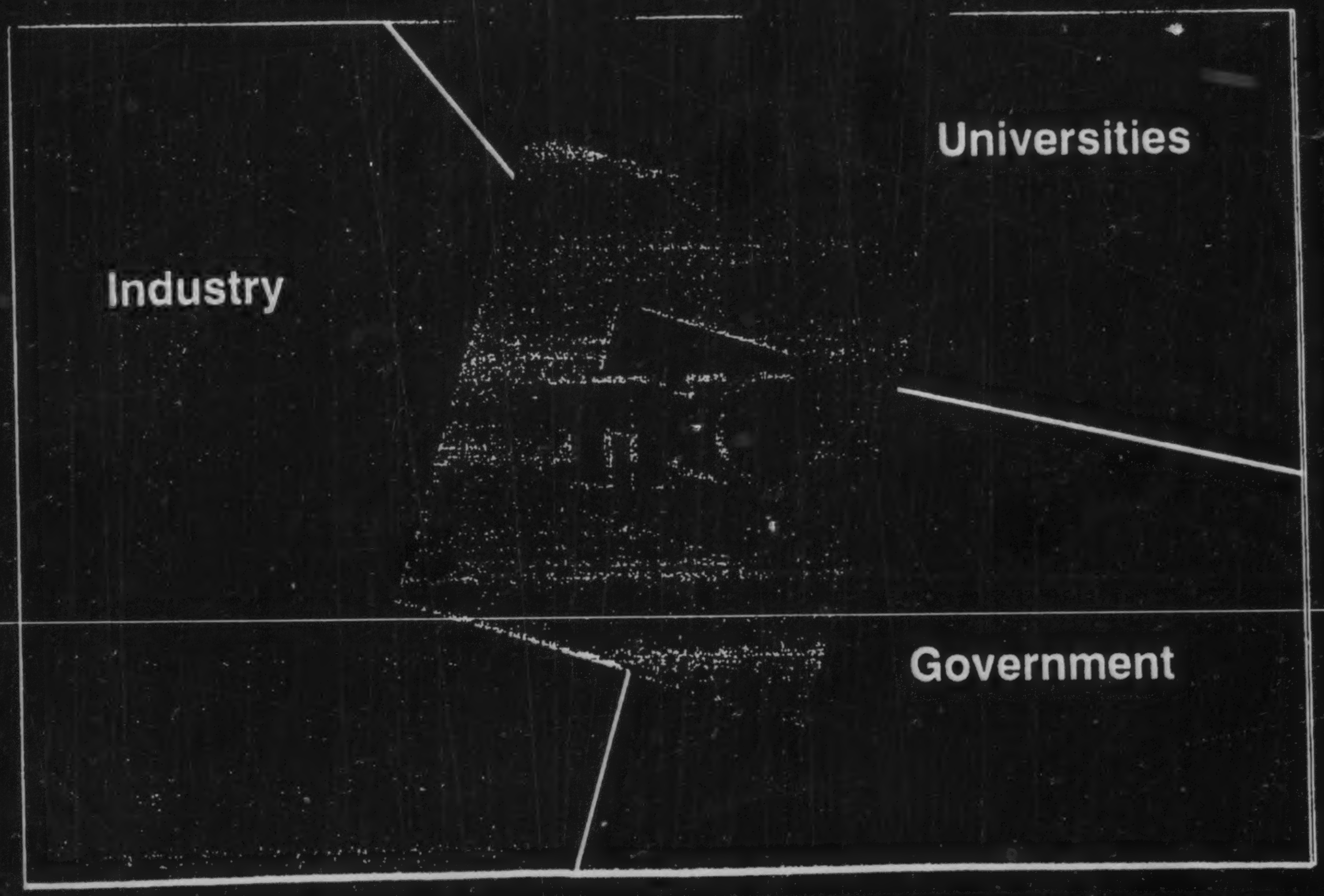
NATO:
AC225/III/WG3
AC225/III/WG4

Netherlands Organization for
Applied Scientific Research

Features of TNO

- Contract Research Organization
- Market-oriented
- Broad knowledge and technology basis
- Actively involved in the application of R&D results
- International in scope
- Objective and independent

Position of TNO in the Dutch infrastructure


Universities
Industry
Government

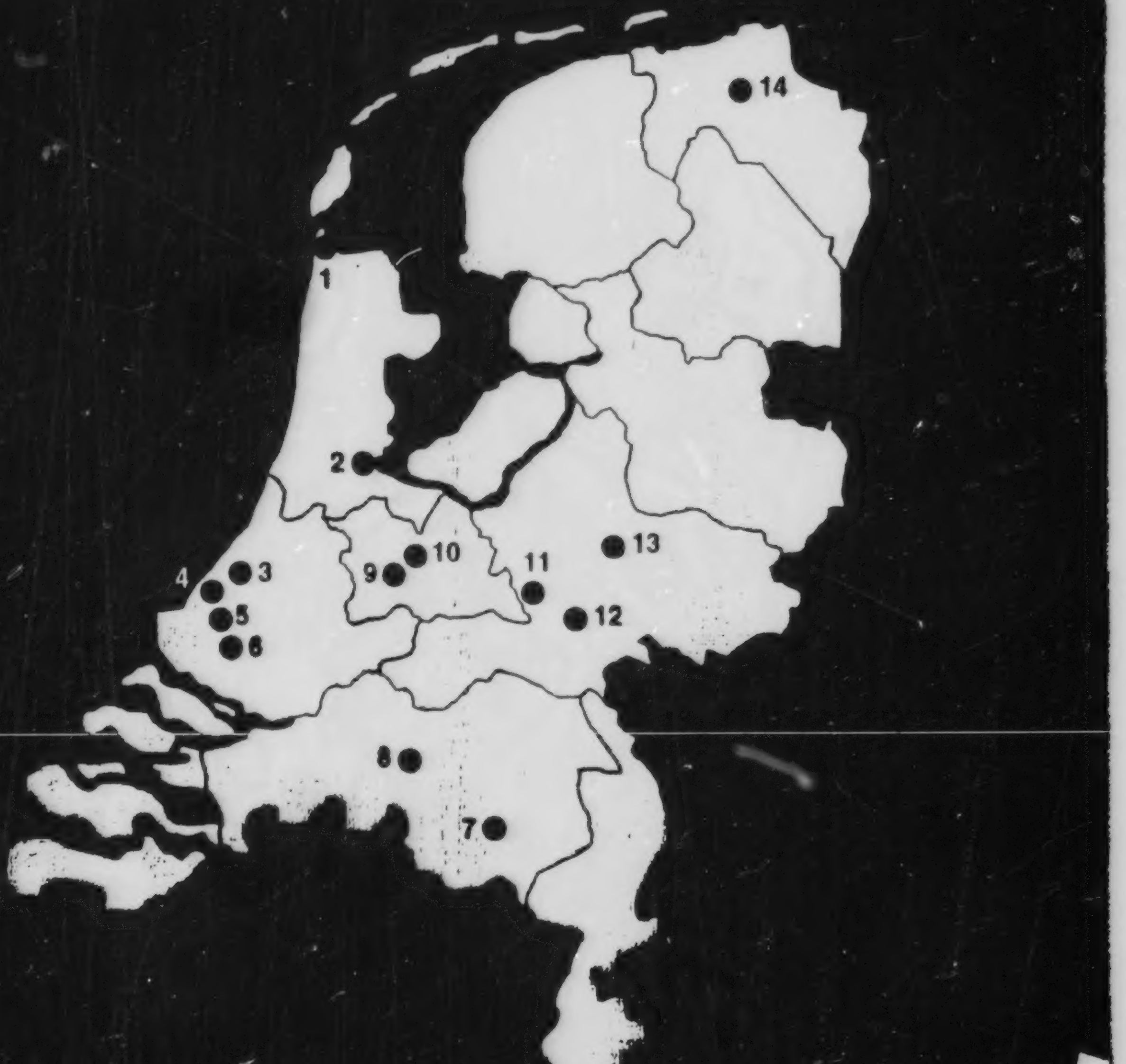
TNO employees

- More than 4,000 employees
- 44% with university training
- 22% with higher vocational training
- 43 TNO professors
- 11 senior research fellows

LIQU FLOW
LIQU FLOW

TNO locations

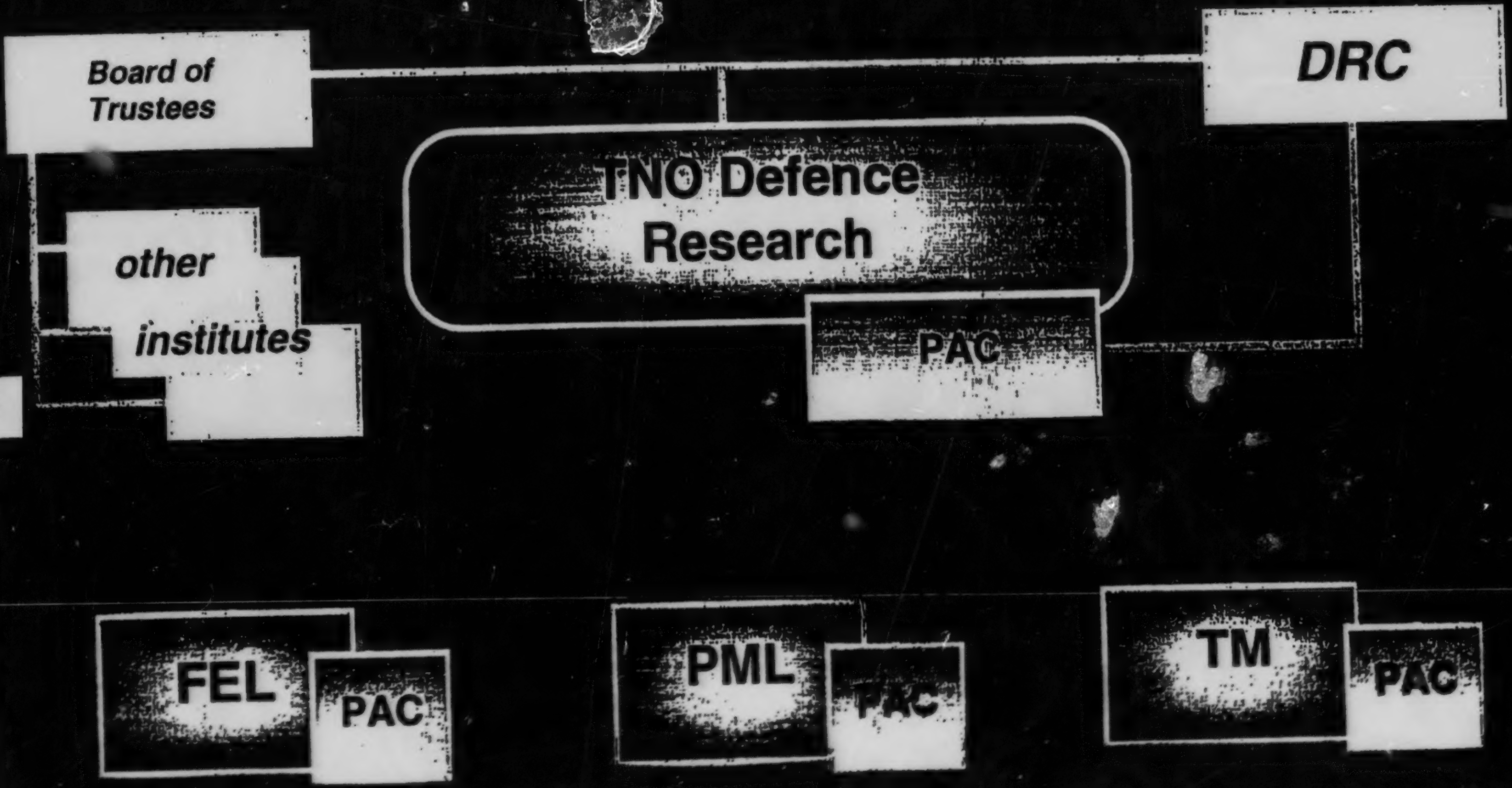
1. Den Helder
2. Amsterdam
3. Leiden
4. The Hague
5. Rijswijk
6. Delft
7. Eindhoven
8. Waalwijk
9. Zeist
10. Soesterberg
11. Wageningen
12. Arnhem
13. Apeldoorn
14. Groningen


14
1
2
13
10
9
11
3
4
12
5
6
8
7

Main fields of activity of TNO

- Industrial technology
- Agro / Food
- Defence
- Health
- Technology policy
- Environment and energy
- Building technology
- Transport and infrastructure

TNO Defence Research



Board of Trustees

DRC

TNO Defence Research

PAC

other institutes

FEL

PAC

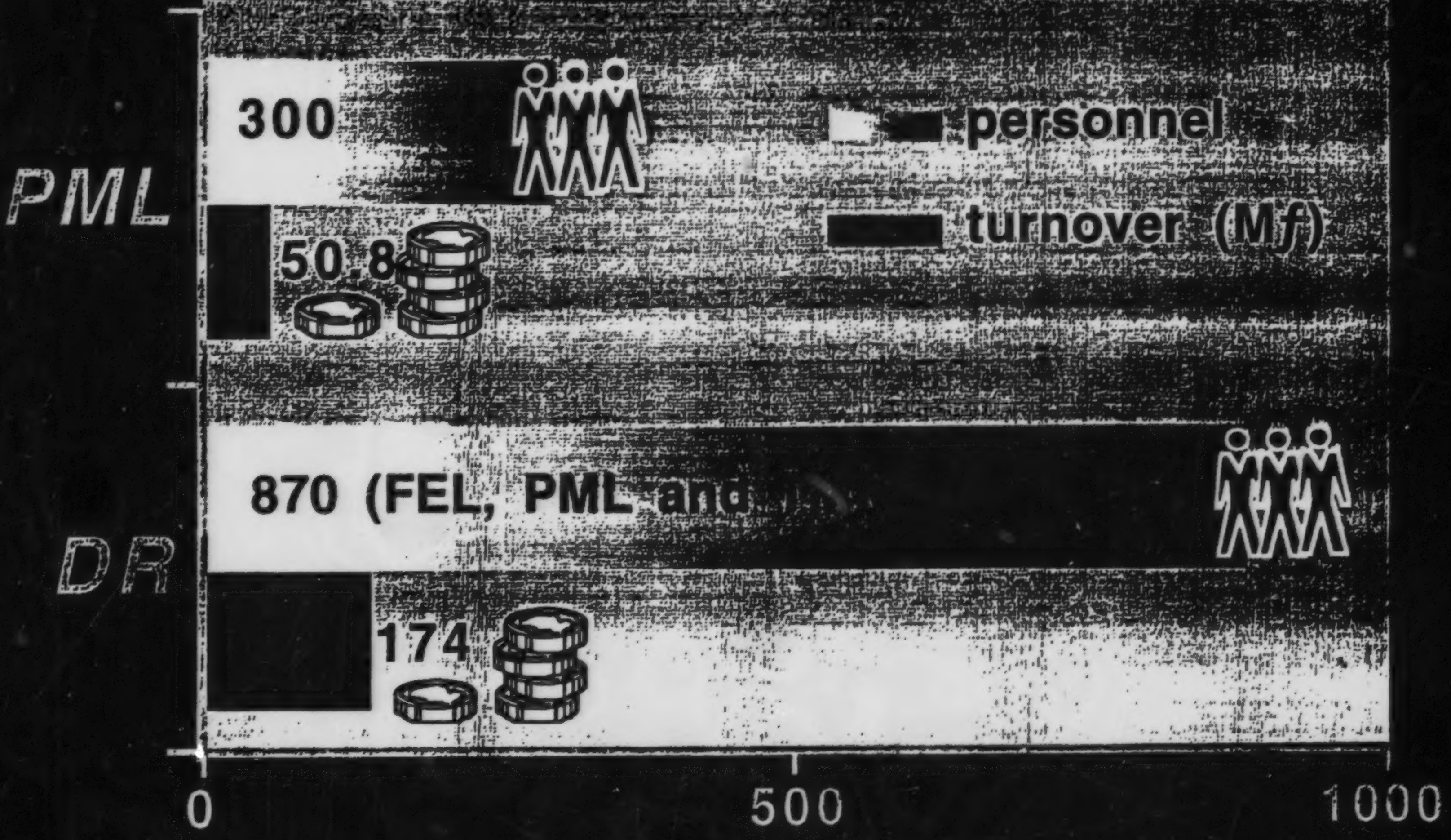
PML

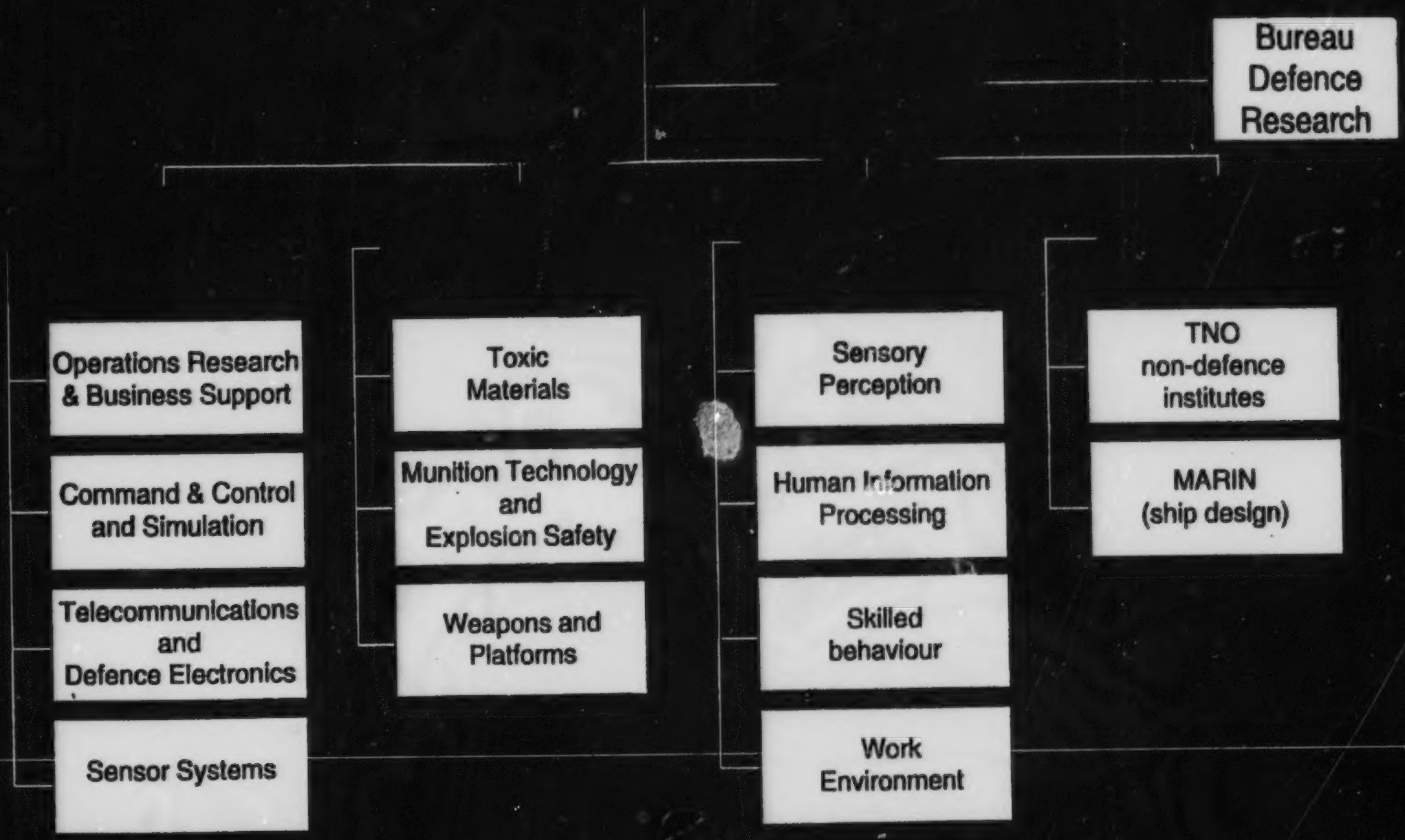
PAC

TM

PAC

Key figures 1995





Bureau Defence Research

Operations Research & Business Support

Command & Control and Simulation

Telecommunications and Defence Electronics

Sensor Systems

Toxic Materials

Munition Technology and Explosion Safety

Weapons and Platforms

Sensory Perception

Human Information Processing

Skilled behaviour

Work Environment

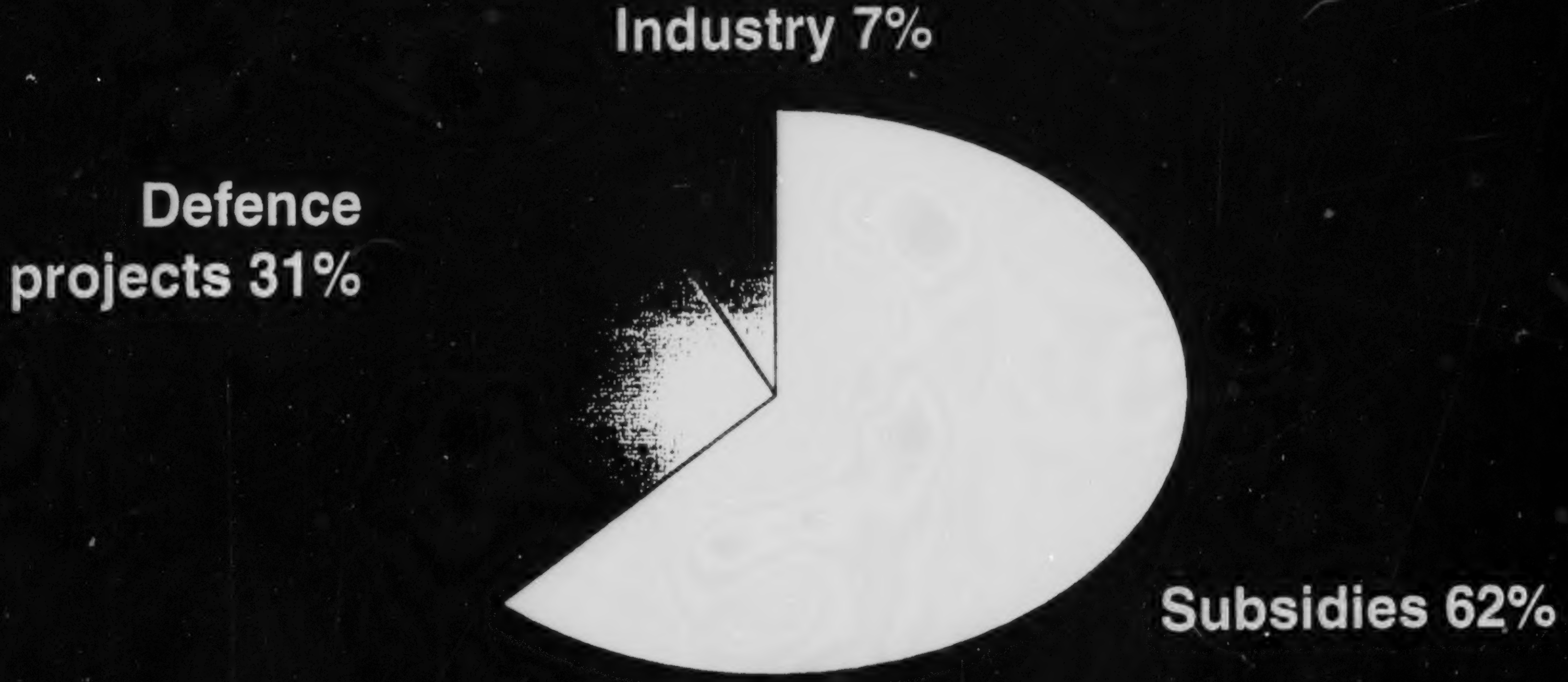
TNO non-defence institutes

MARIN (ship design)

Defence Research

947569E 5

Program funding (1996)



Involvement TNO Human Factors Research Institute in SMP:

*Physiological stress and body cooling

*Integrated head protection

*Integrated foot protection

Design of protective clothing and equipment

Head mounted displays

Active noise reduction

Speech technology

Computer supported target acquisition

Perception of sensor fused images

* Directly related to SMP, other topics also independently investigated

Involvement TNO Human Factors Research Institute in SMP (continued):

Systems ergonomics

Decision processes using C^3I

Soldier-system interface

Teleoperation of weapons

Networked battlefield simulation

in the Netherlands, TNO-FEL

Sensors

- radar, radiometry, acoustic/seismic
- threatsignature
- atmospheric effects
- visibility
- false alarm
- processing
- detection models
- multisensor, sensor fusing
- minefield detection
- combat ID

in the Netherlands, TNO-FEL

Countermeasures

- decoys
- jammers
- camouflage
- adaptive camouflage (stealth)
- smoke

in the Netherlands, TNO-FEL

Operational research

- op. requirements
- tactics
- force structure analysis
- wargaming
- technology assessment
- man-in-the-loop simulator coupled to synthetic battlefield

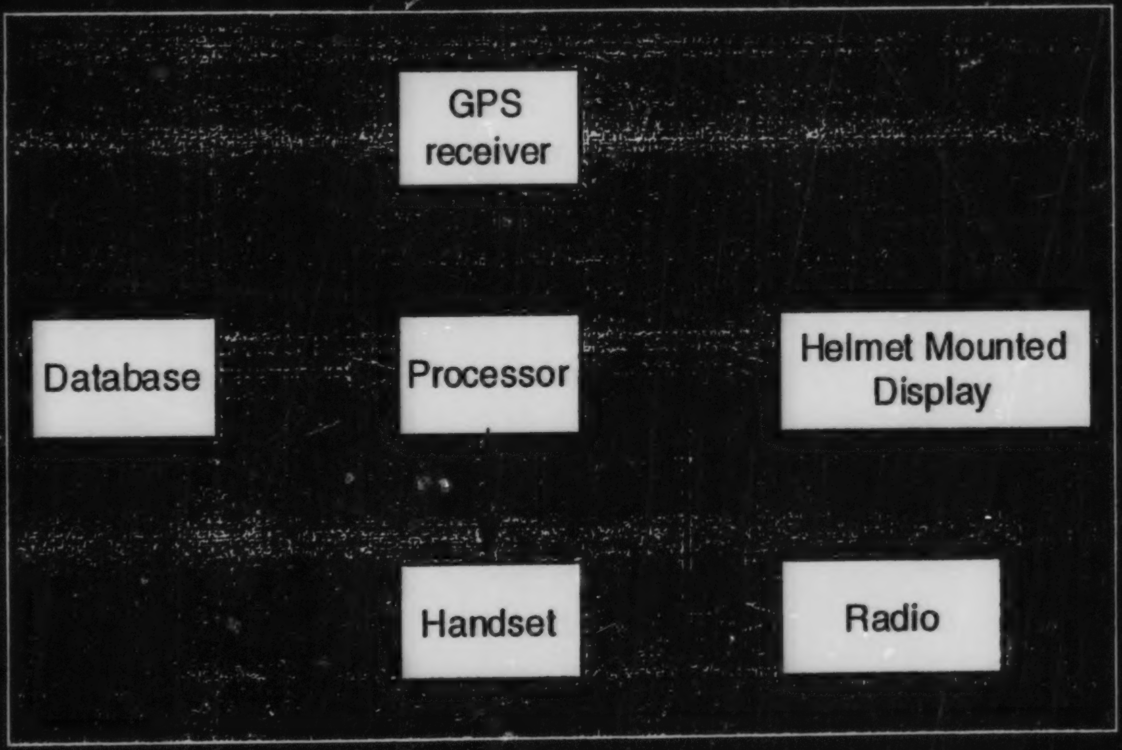
SMP subjects at TNO-PML

- **Survivability**
  - Ballistic protection
  - Chemical protection
  - Flame/flash protection
  - B/C threat sensors
  - Decontamination
  - Water purification
- **Lethality**
  - PDW, ICW, CSW
  - KE, fragmenting, SC munitions
  - Other infantry weapons and munitions
  - Pyrotechnics
- **System integration**
  - Technologies
  - Capabilities
  - PML + FEL + HFRI + RNLA + ...

Focus projects

- Soldier Day
- Situational Awareness
- Remote weapon sight

Soldier Digital Assistant



GPS receiver
Database
Processor
Helmet Mounted Display
Handset
Radio

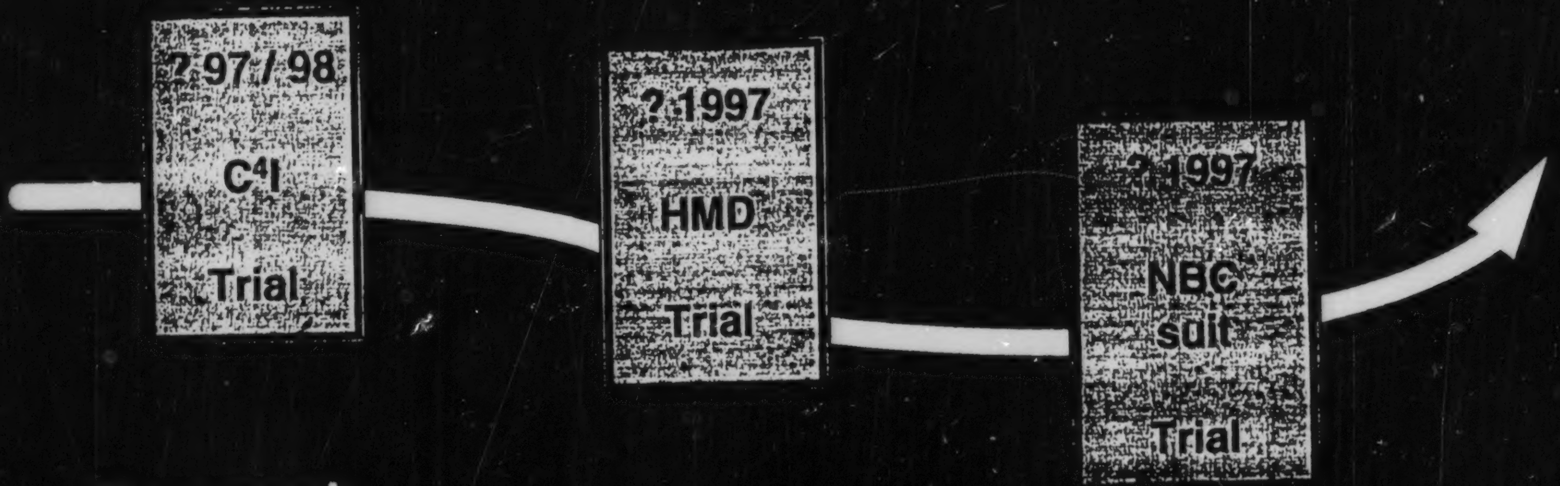
Possible new focus projects

- Integrated head protection
- Evaluation environment
- System architecture design
- OICW effectiveness

Soldier Modernisation activities

Integration activities

[illegible]



? 97 / 98
C4I
Trial

? 1997
HMD
Trial

? 1997
NBC suit
Trial

Research

— prototypes —

SMP-related activities

at TNO-PML

Dr. Maarten P.I. Manders

TNO-PML

15 Nov 1995

05-253

SMP subjects at TNO-PML

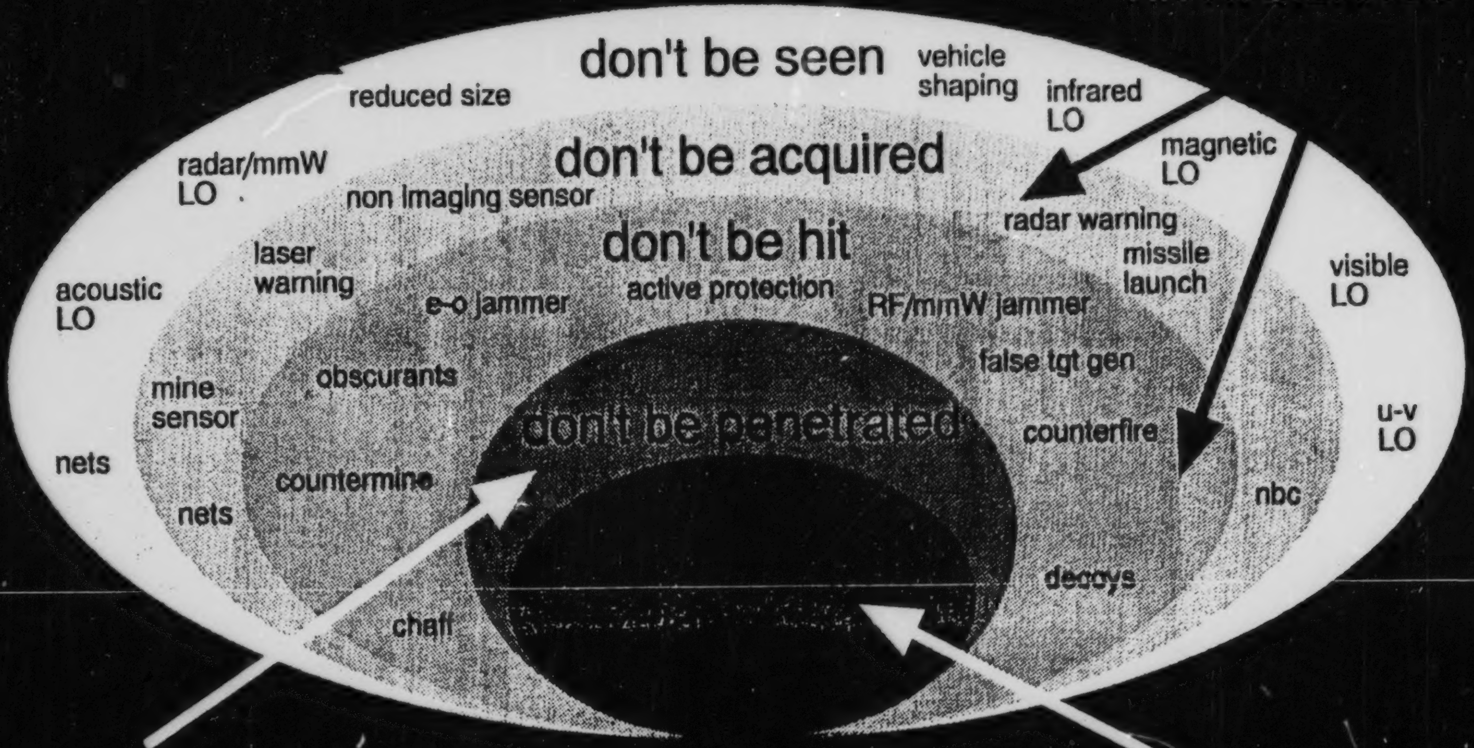
- **Survivability**
  - Ballistic protection
  - Chemical protection
  - Flame/flash protection
  - B/C threat sensors
  - Decontamination
  - Water purification
- **Lethality**
  - PDW, ICW, CSW
  - KE, fragmenting, SC munitions
  - Other infantry weapons and munitions
  - Pyrotechnics
- **System integration**
  - Technologies
  - Capabilities
  - PML + FEL + HFRI + RNLA + ...

Survivability

DETECTION AVOIDANCE

SUSCEPTIBILITY
REDUCTION

HIT AVOIDANCE



don't be seen

don't be acquired

don't be hit

don't be penetrated

reduced size

vehicle
shaping

infrared
LO

radar/mmW
LO

magnetic
LO

non imaging sensor

radar warning

laser
warning

missile
launch

acoustic
LO

e-o jammer

active protection

RF/mmW jammer

visible
LO

obscurants

false tgt gen

mine
sensor

u-v
LO

counterfire

nets

countermine

nets

nbc

decoys

chaff

PENETRATION AVOIDANCE

VULNERABILITY
REDUCTION

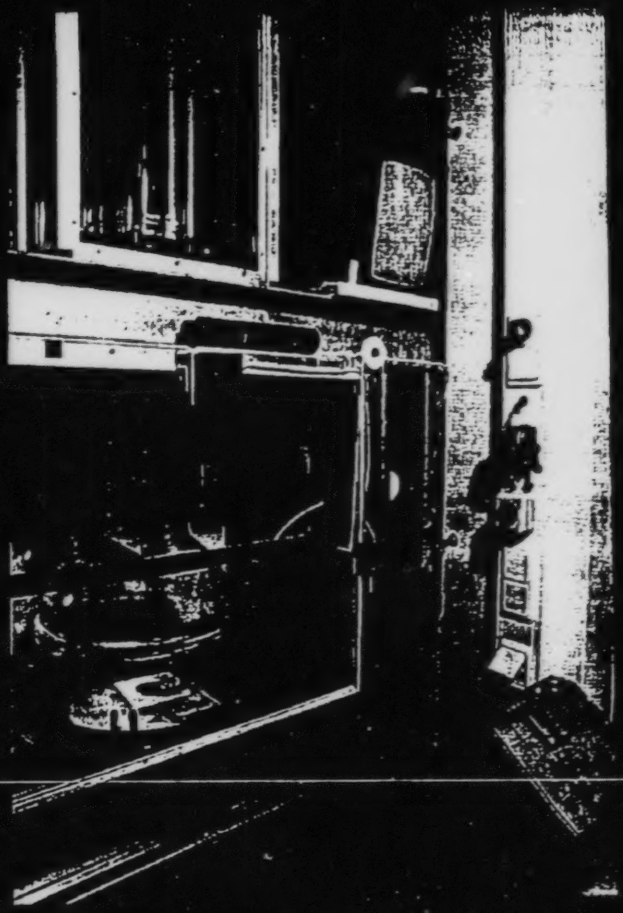
KILL AVOIDANCE

PM Survivability Systems, Armored Systems Modernization (1992)

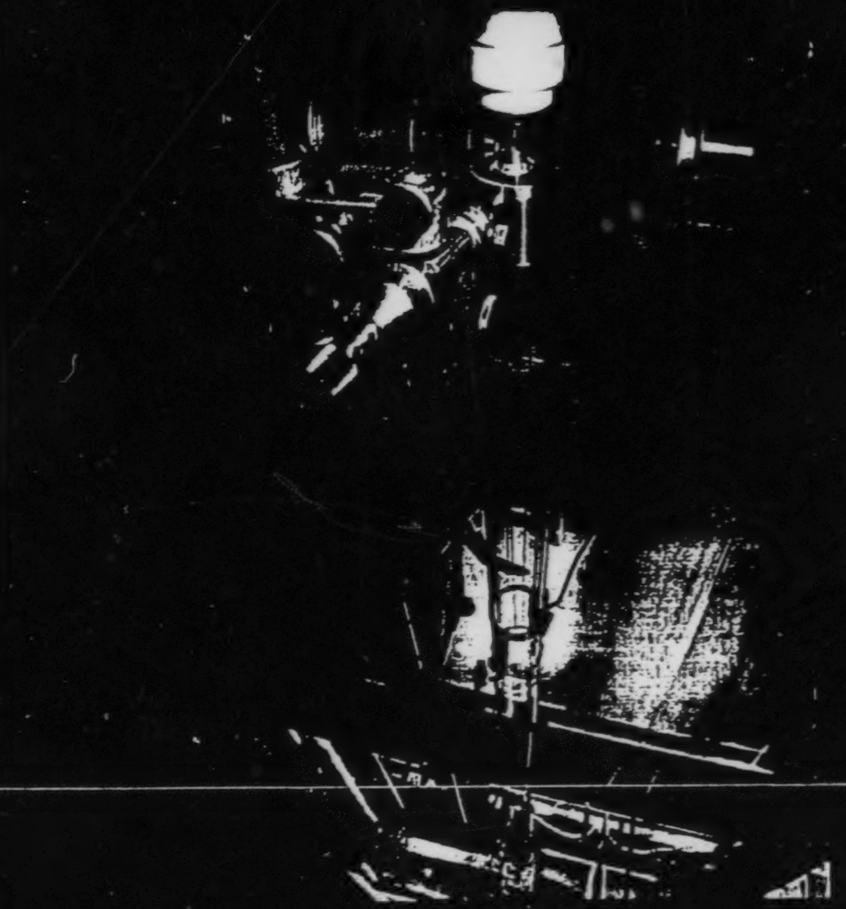
6

Personal protective equipment

Liquid tests



0.8-2 μl drop
falling from 2 m height

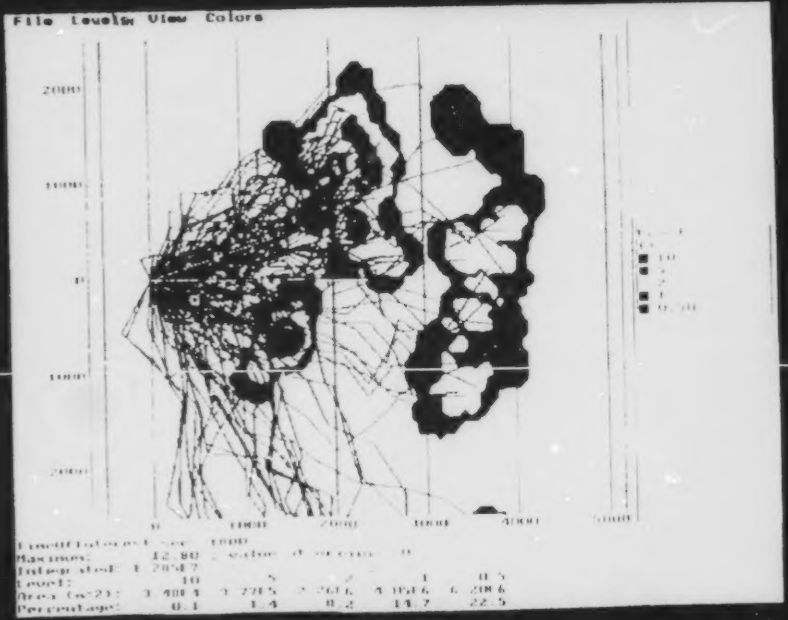


4-80 μl thickened agent drop
falling from 7.5 m height

Measurement of the face seal leakage by means of SF6

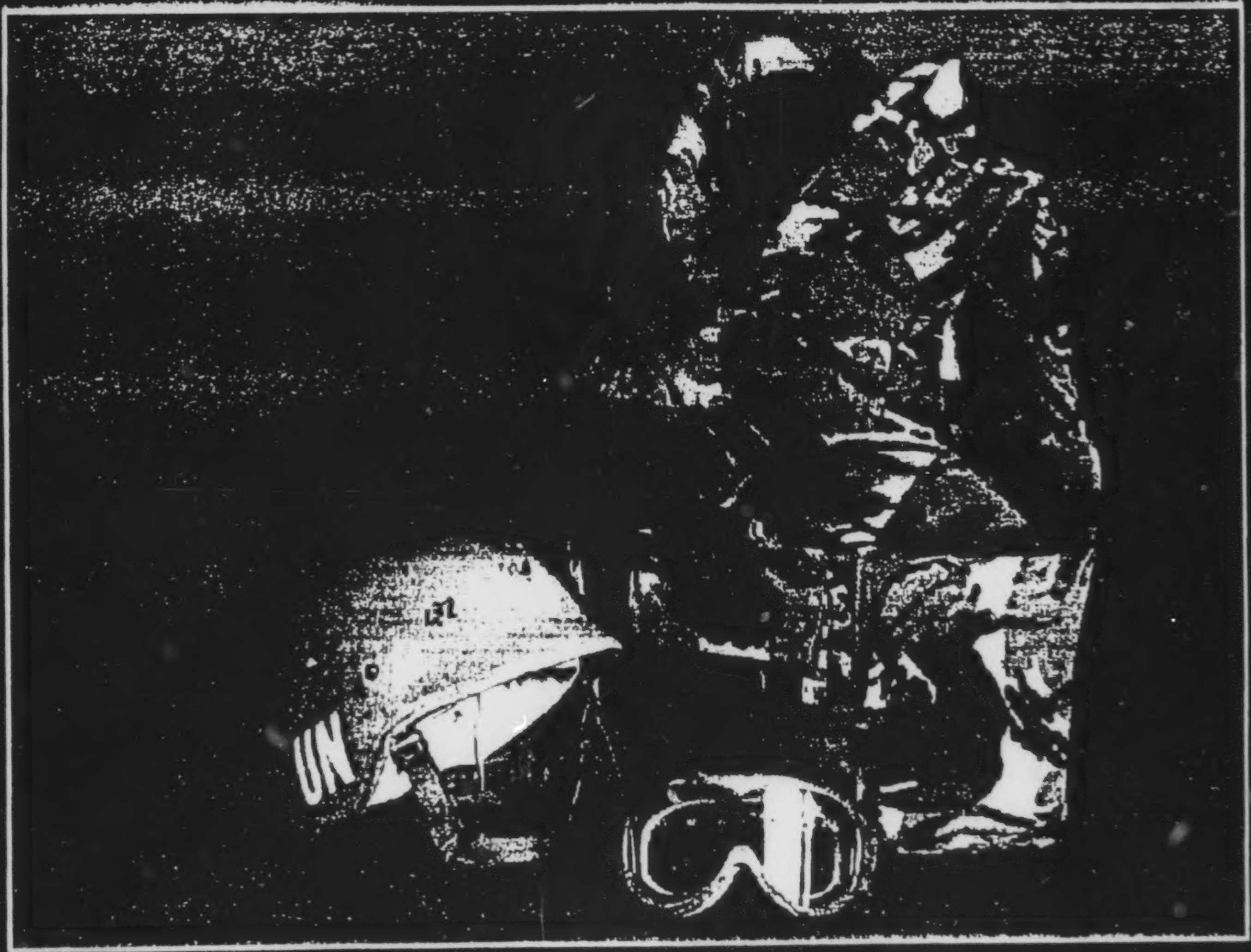
Implementation: Monte Carlo simulation

- Generate Meteo ensembles
- Generate Meander ensembles
- Track all paths of puffs


File
Levels
View
Colors
2000
1000
0
1000
2000
0
1000
2000
3000
4000
5000

```
Maximum:        12.80
Integrated: 1.70587
Level:            10        5        2        1      0.5
Area (m^2):   [illegible]
Percentage:      0.1      1.4      8.2     14.7     22.5
```

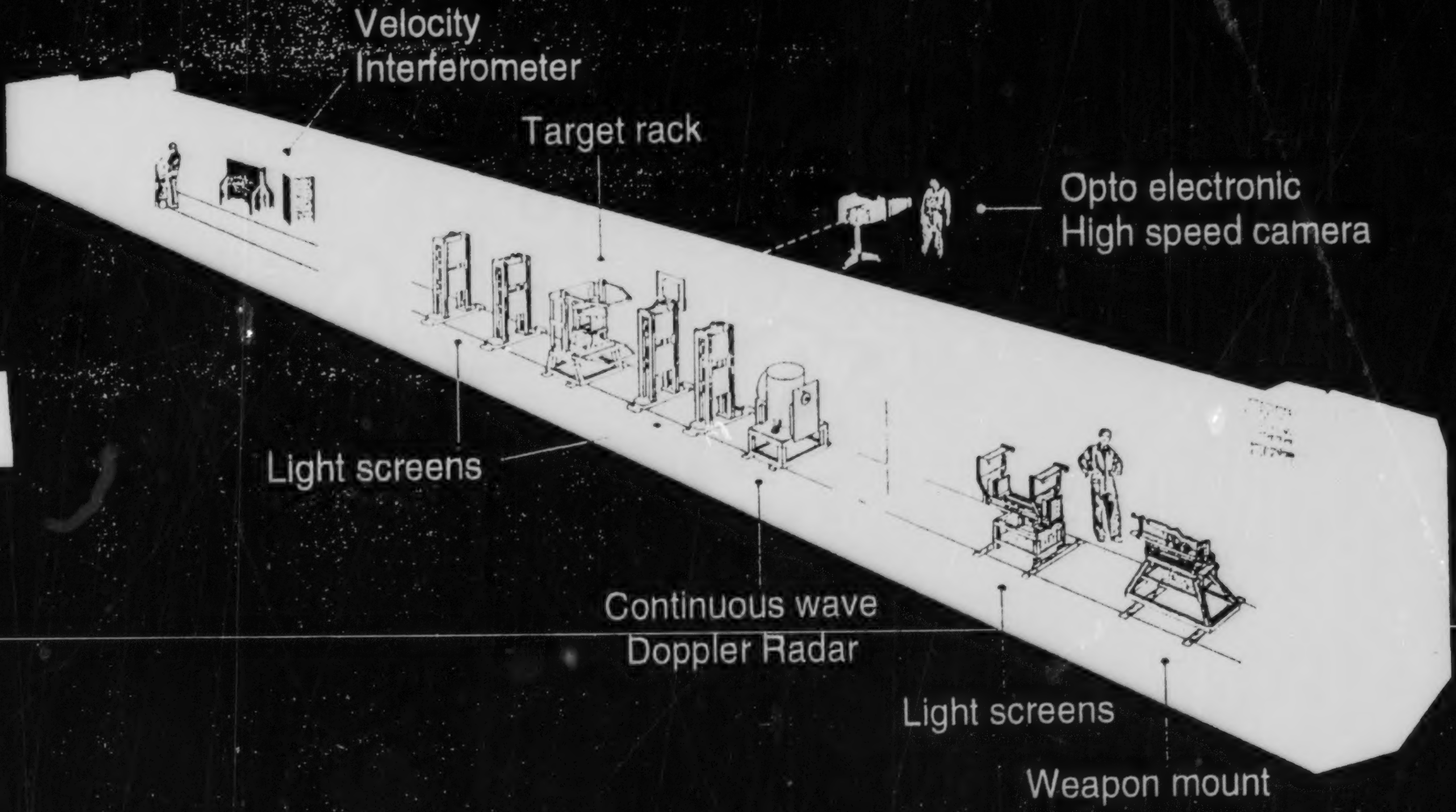
Ballistic Protective Equipment



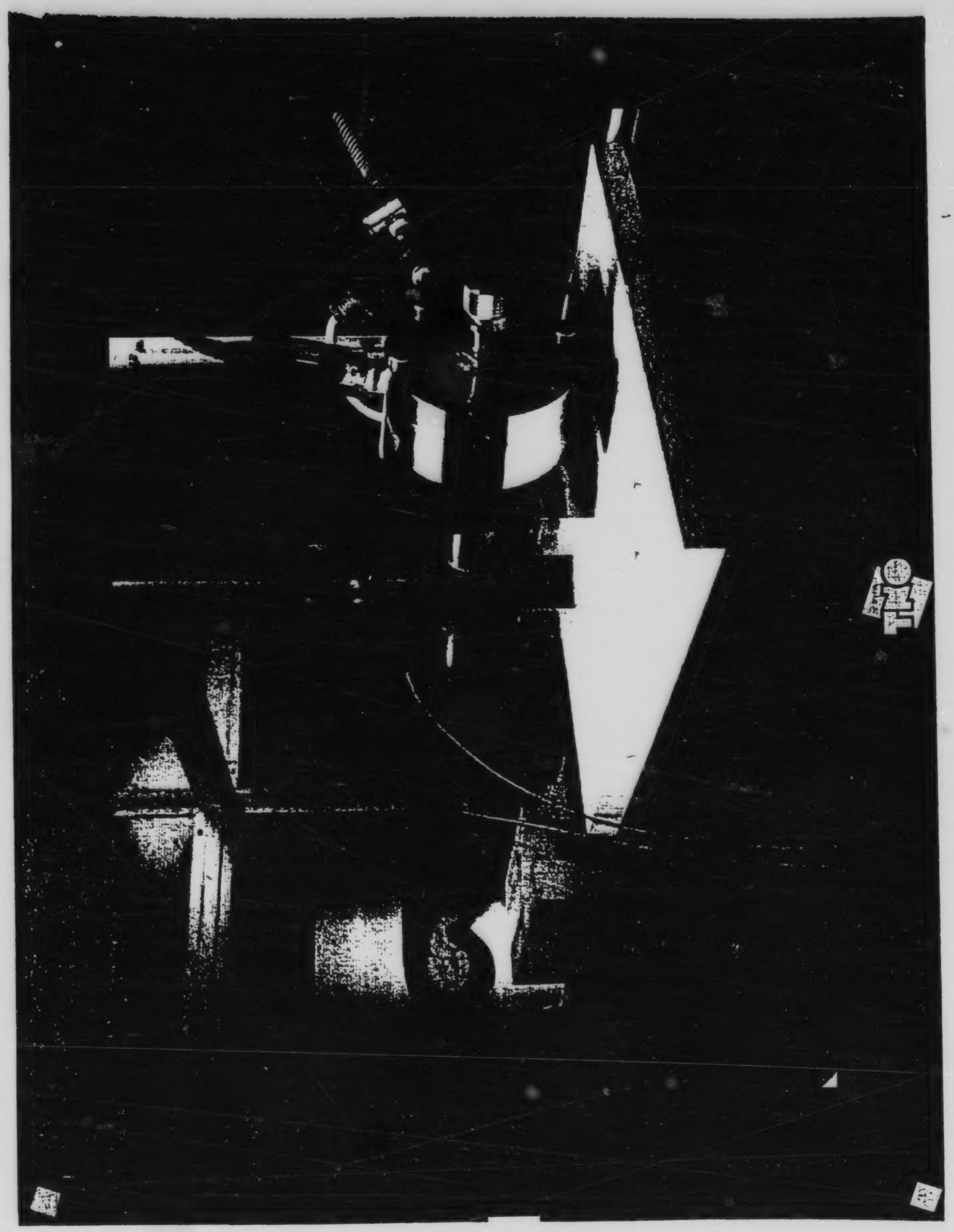
95-266

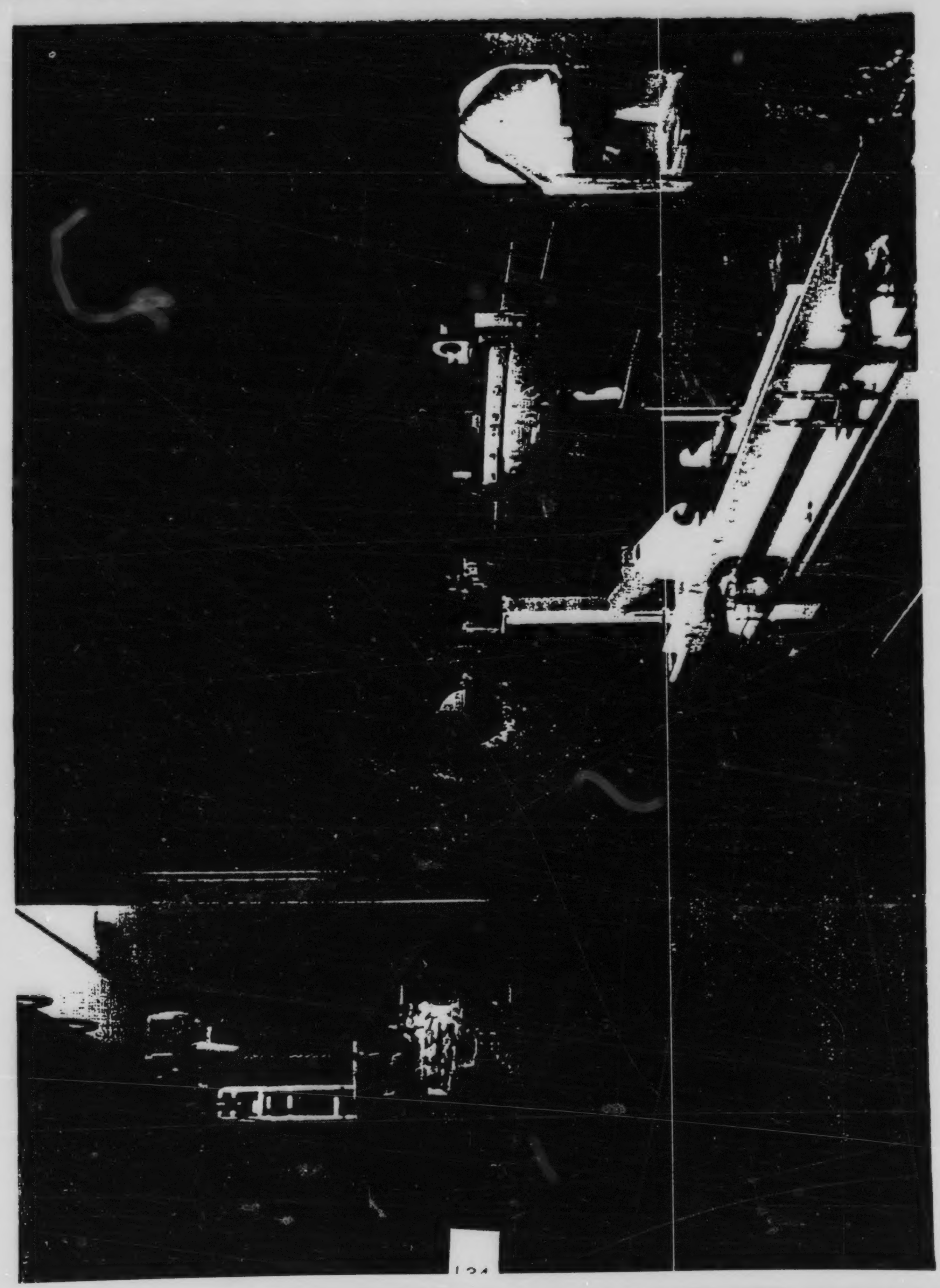
Test Facility TNO-PML

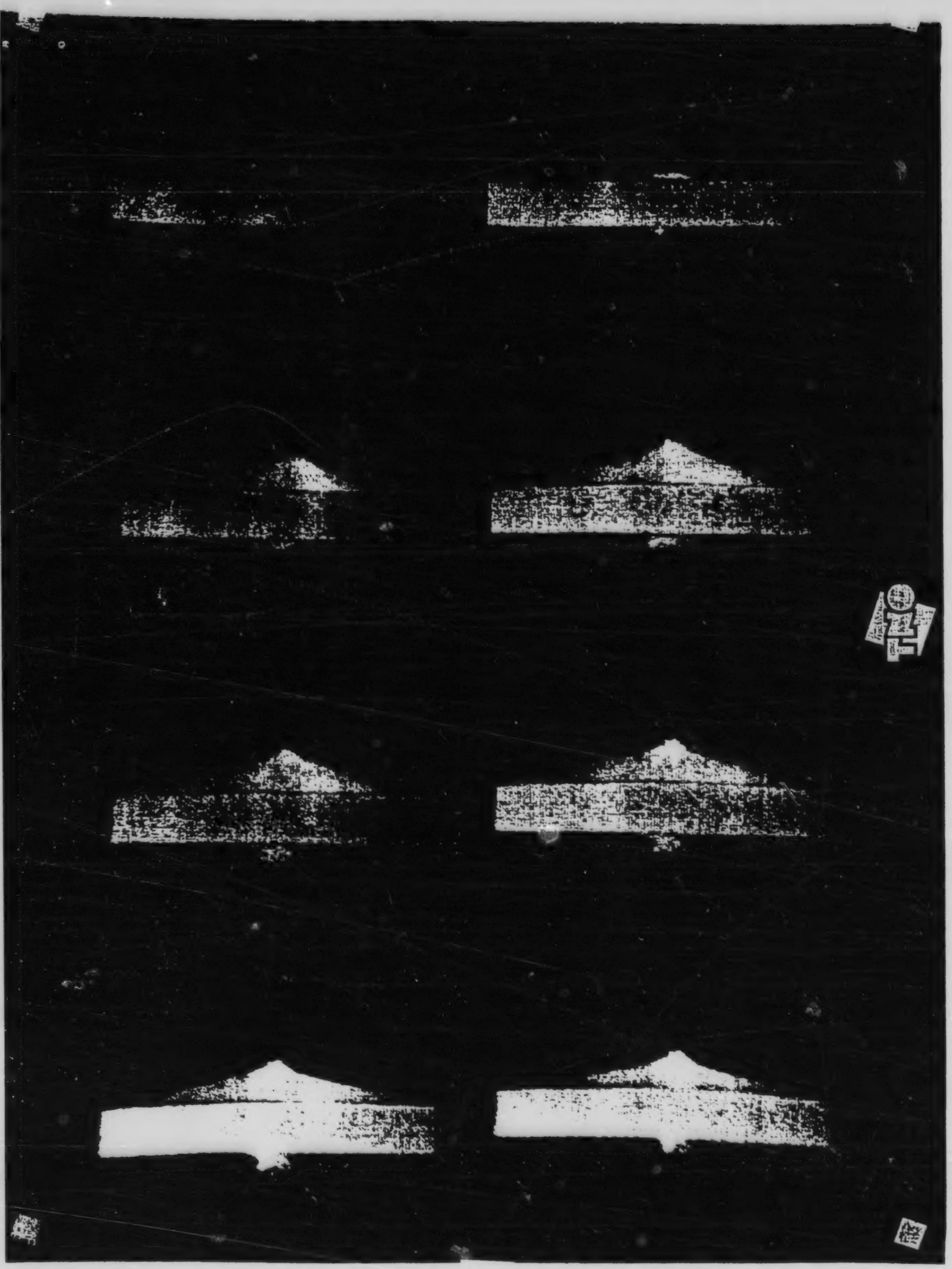
small - to middle calibre (up to 25 mm)

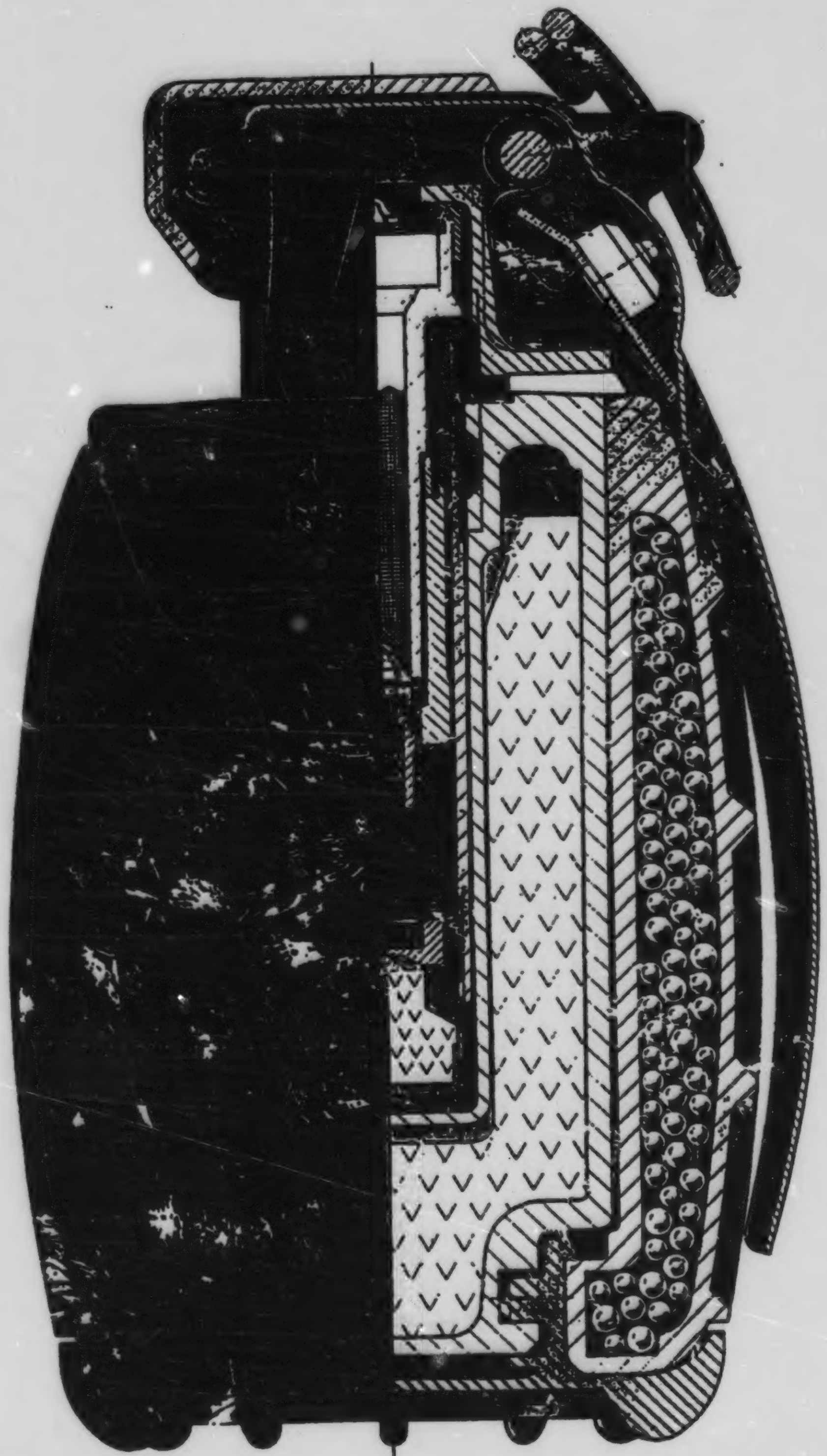

Velocity
Interferometer
Target rack
Opto electronic
High speed camera
Light screens
Continuous wave
Doppler Radar
Light screens
Weapon mount

95-219

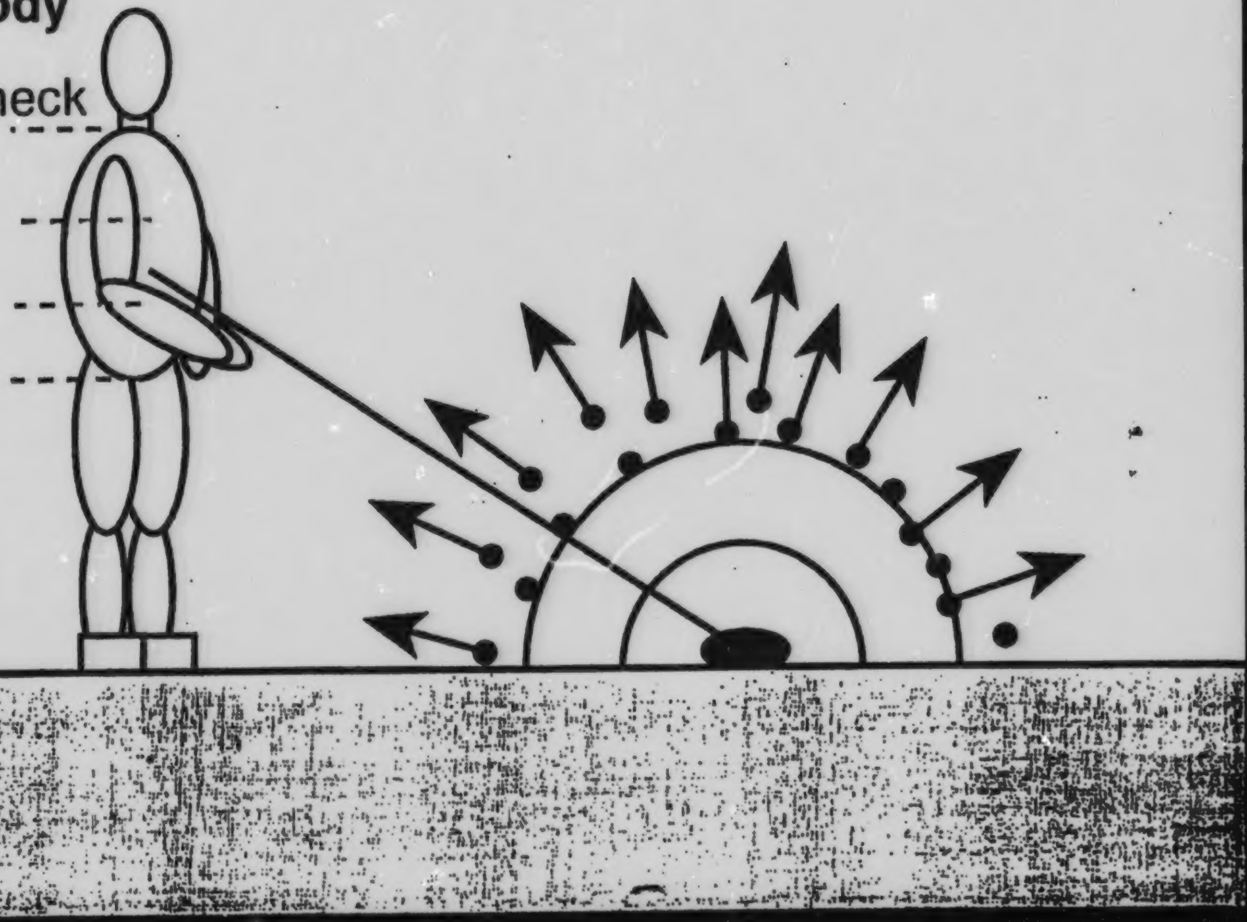








Standing personnel



Parts of body

Head and neck

Thorax

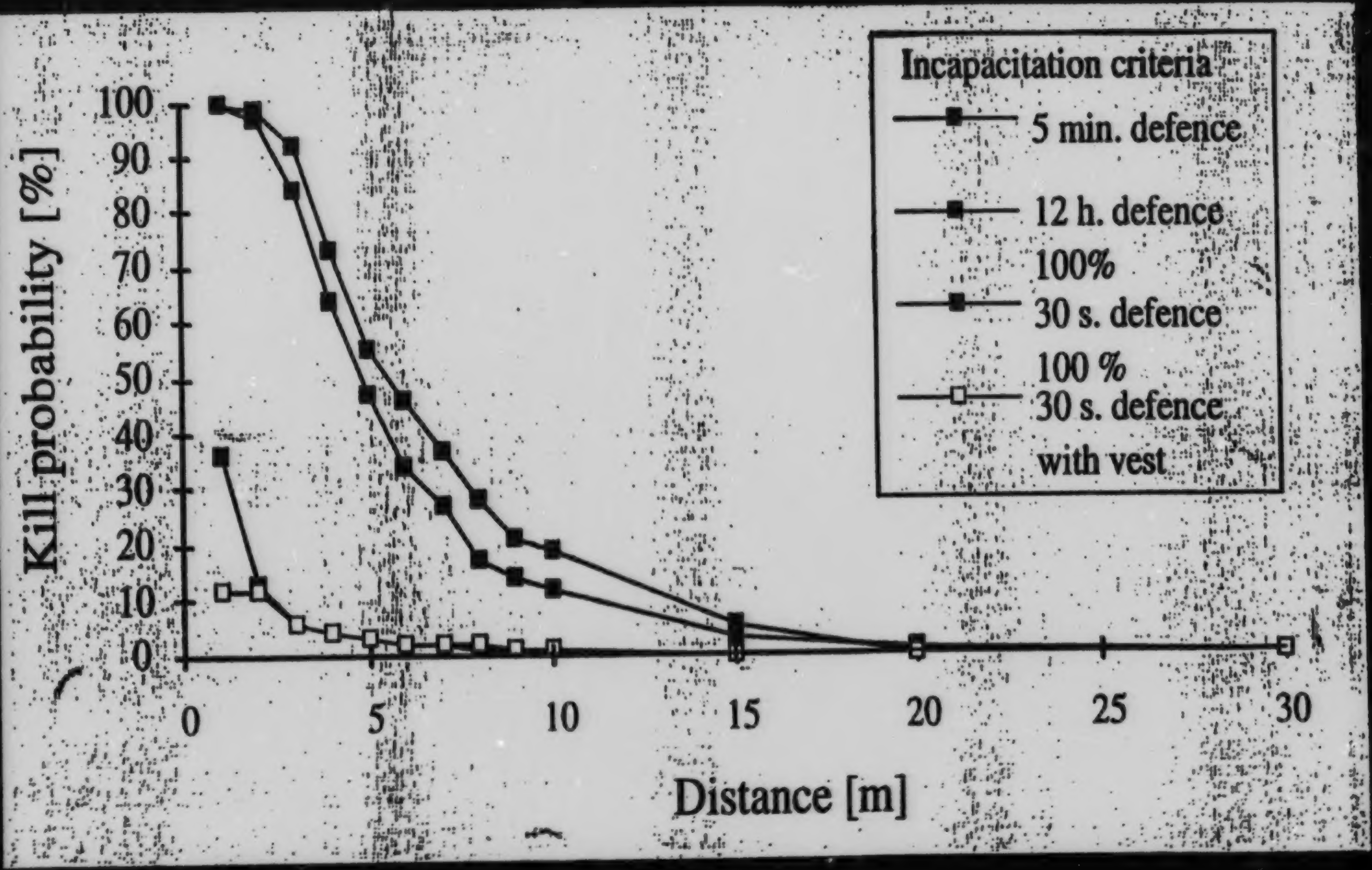
Abdomen

Pelvis

Arms

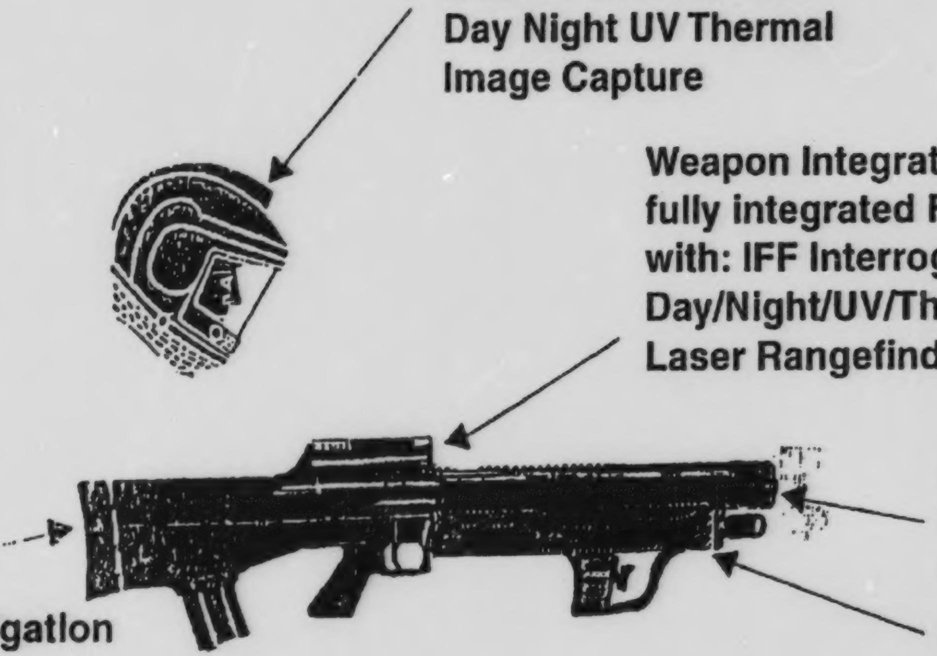
Legs

Comparison of incapacitation criteria



NATO Industrial Advisory Group
Sub-Group 48

Conclusions of the Weapons Team (Team 5)



Helmet-mounted Colour
CCD TV Camera with
Day Night UV Thermal
Image Capture

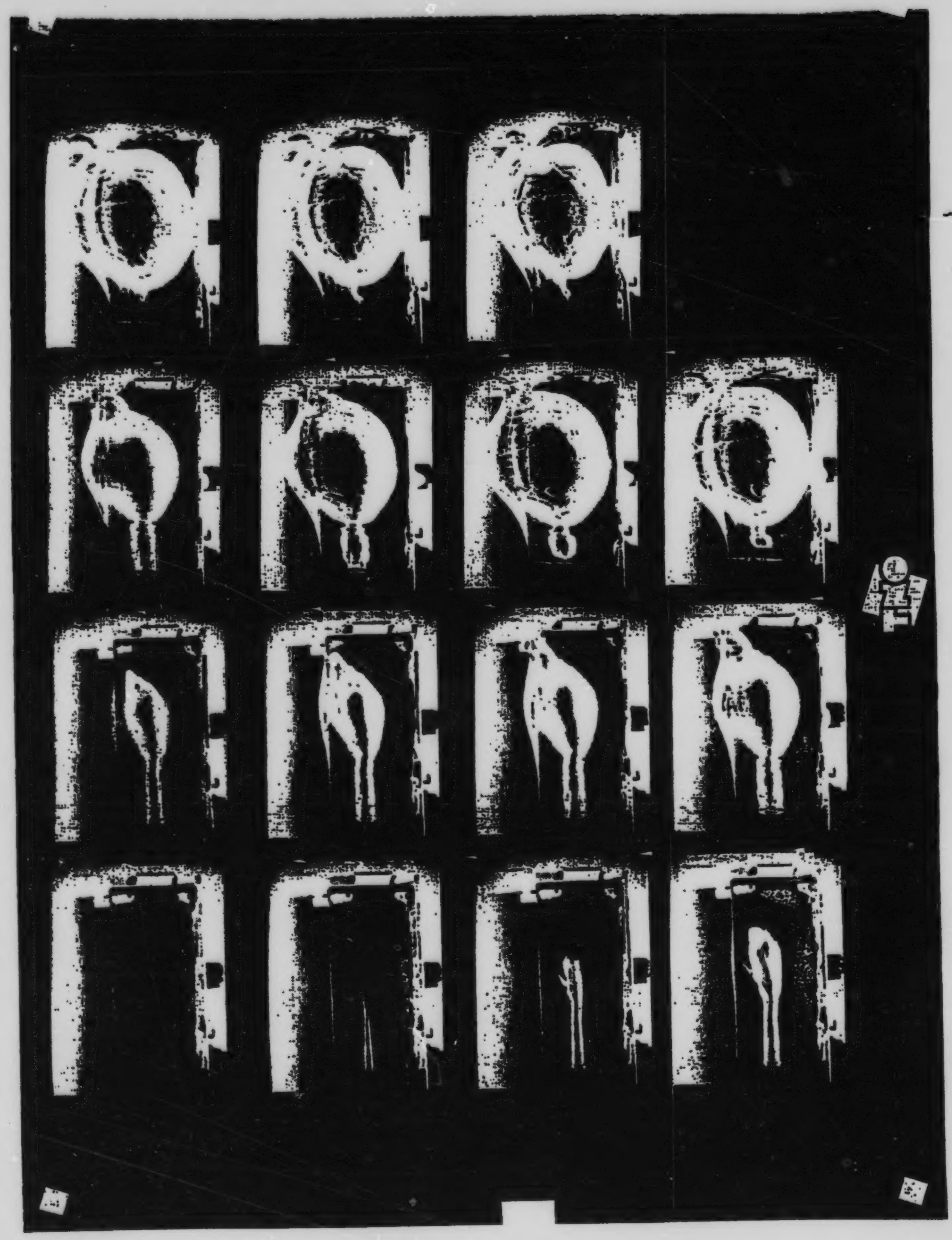
Weapon Integrated 2nd Generation
fully integrated Fire Control System
with: IFF Interrogator
Day/Night/UV/Thermal Vision
Laser Rangefinder Ballistic computer

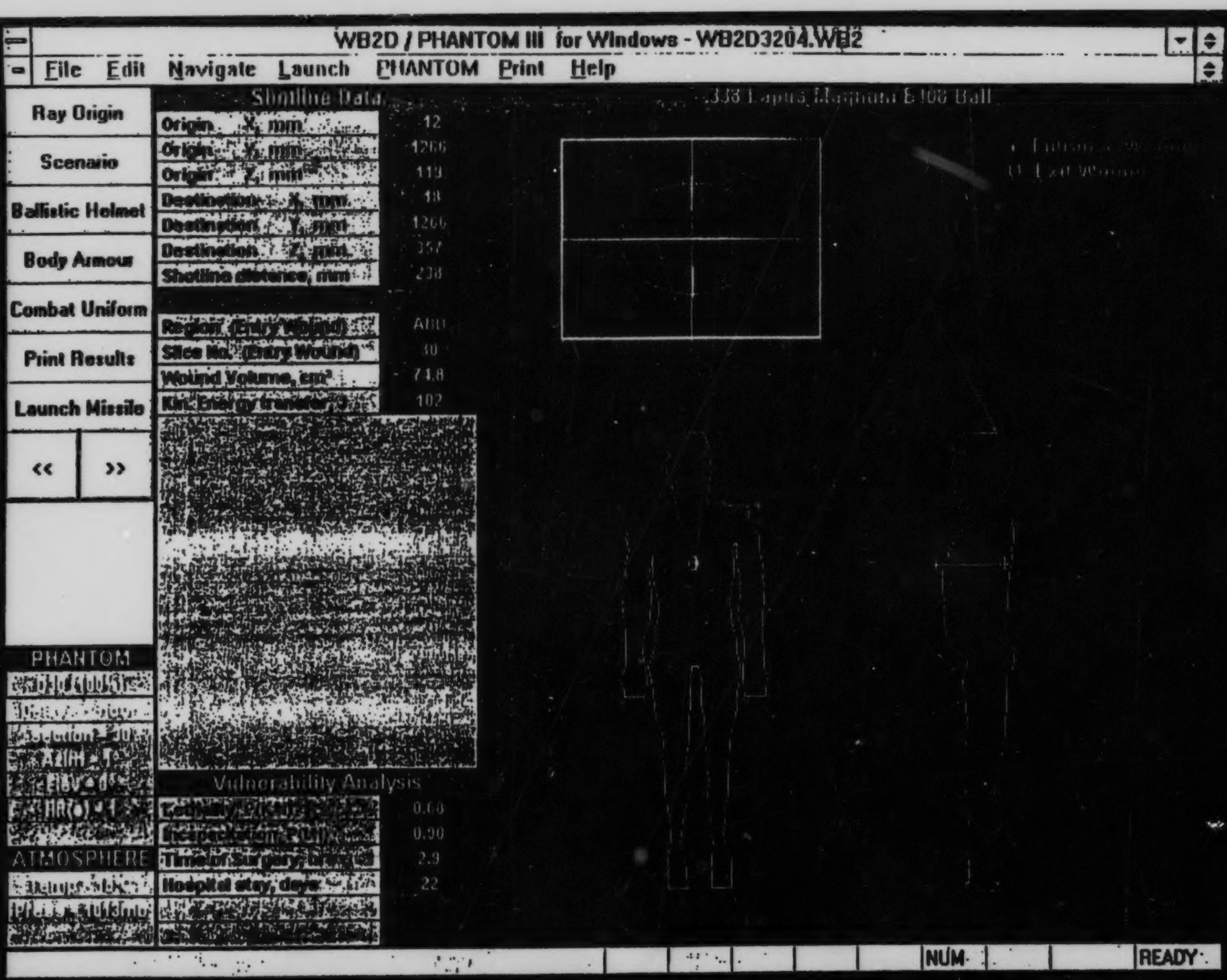
Improved Air Burst
ammunition. High
number of fragments.

Integrated KE-weapon
(PDW)

Improved
Recoil Mitigation

Far-Term Straw Man, Weapons




WB2D / PHANTOM III for Windows - WB2D3204.WB2
File
Edit
Navigate
Launch
PHANTOM
Print
Help
Ray Origin
Scenario
Ballistic Helmet
Body Armour
Combat Uniform
Print Results
Launch Missile
<<
>>
PHANTOM
ATMOSPHERE
.338 Lapua Magnum B408 Ball
NUM
READY

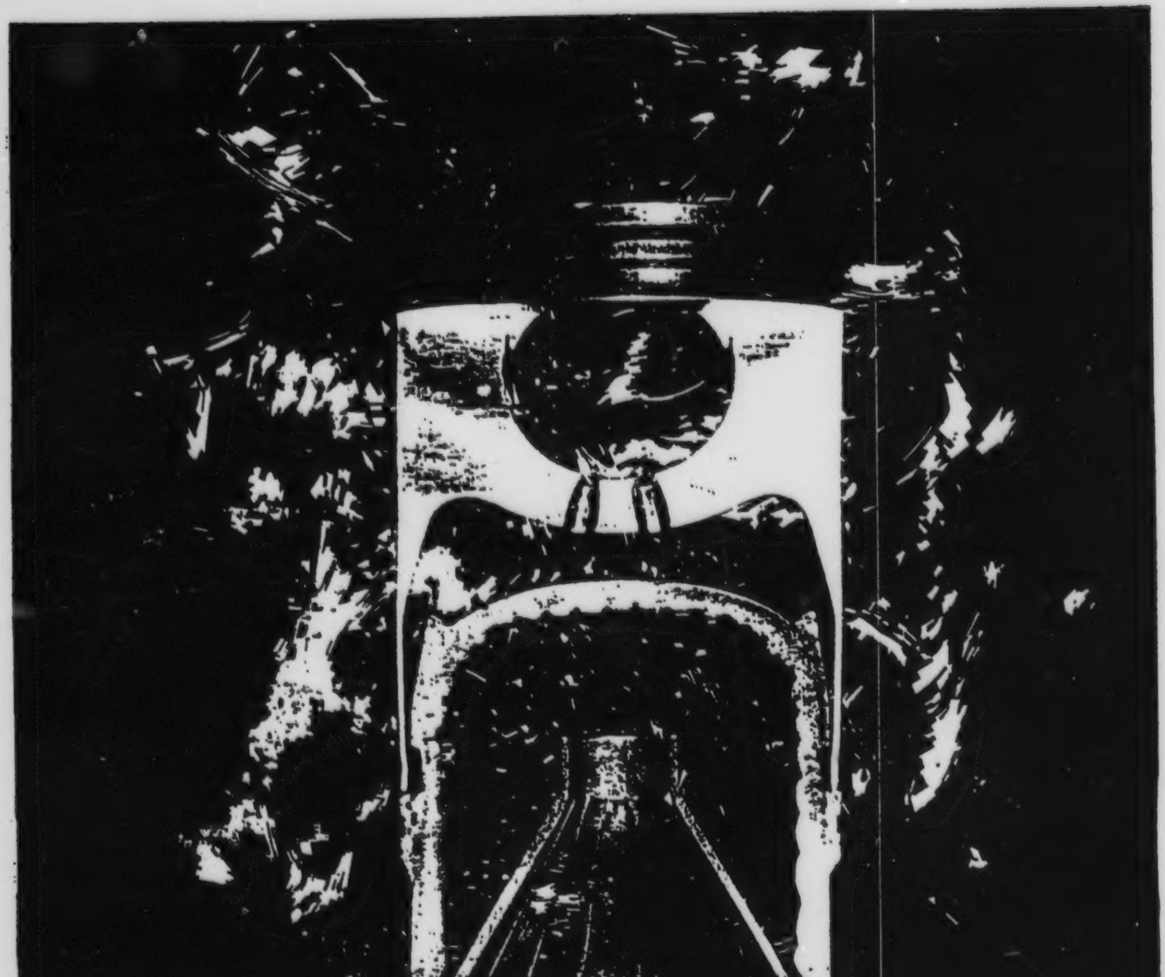
Shotline Data

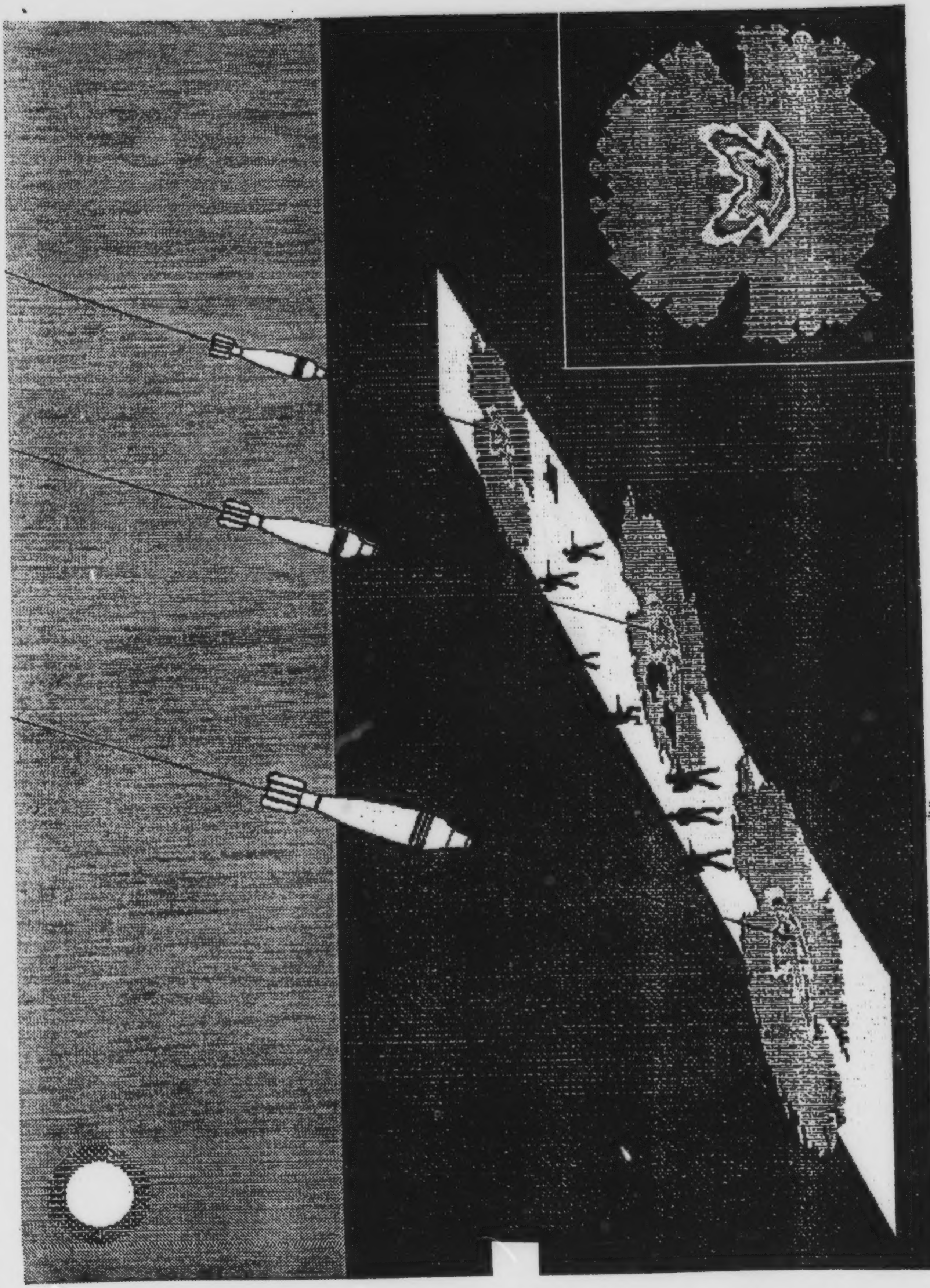
Origin X, mm	12
Origin Y, mm	1266
Origin Z, mm	119
Destination X, mm	18
Destination Y, mm	1266
Destination Z, mm	357
Shotline distance, mm	238
Region (Entry Wound)	ABD
Slice No. (Entry Wound)	30
Wound Volume, cm³	74.8
Kin. Energy transfer, J	102

Vulnerability Analysis

[illegible]	0.68
[illegible]	0.90
Time of Surgery, [illegible]	2.9
Hospital stay, days	22

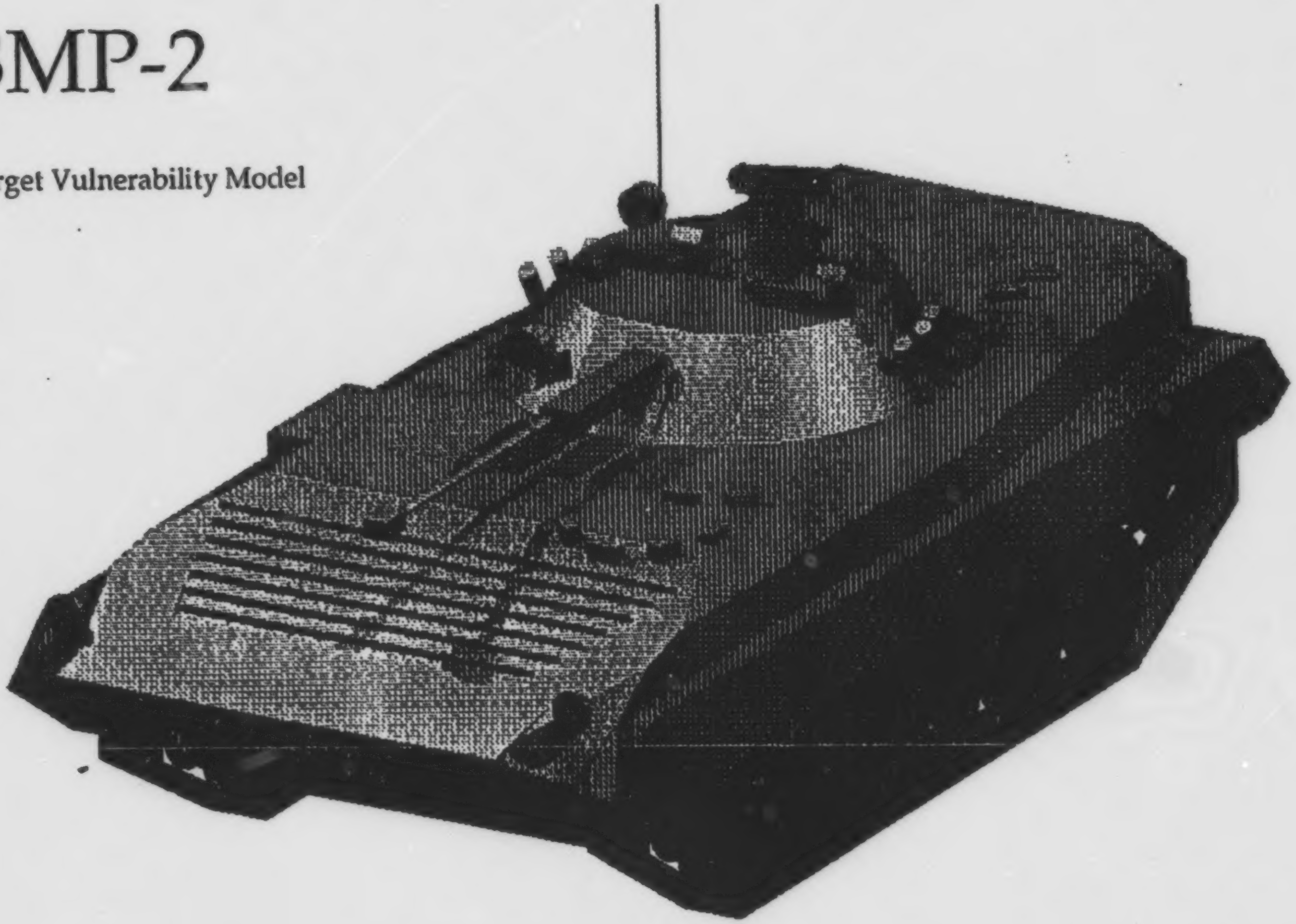
Single Wound Analysis (aimed) of .338 Lapua Sniper at 1000 m in Abdomen

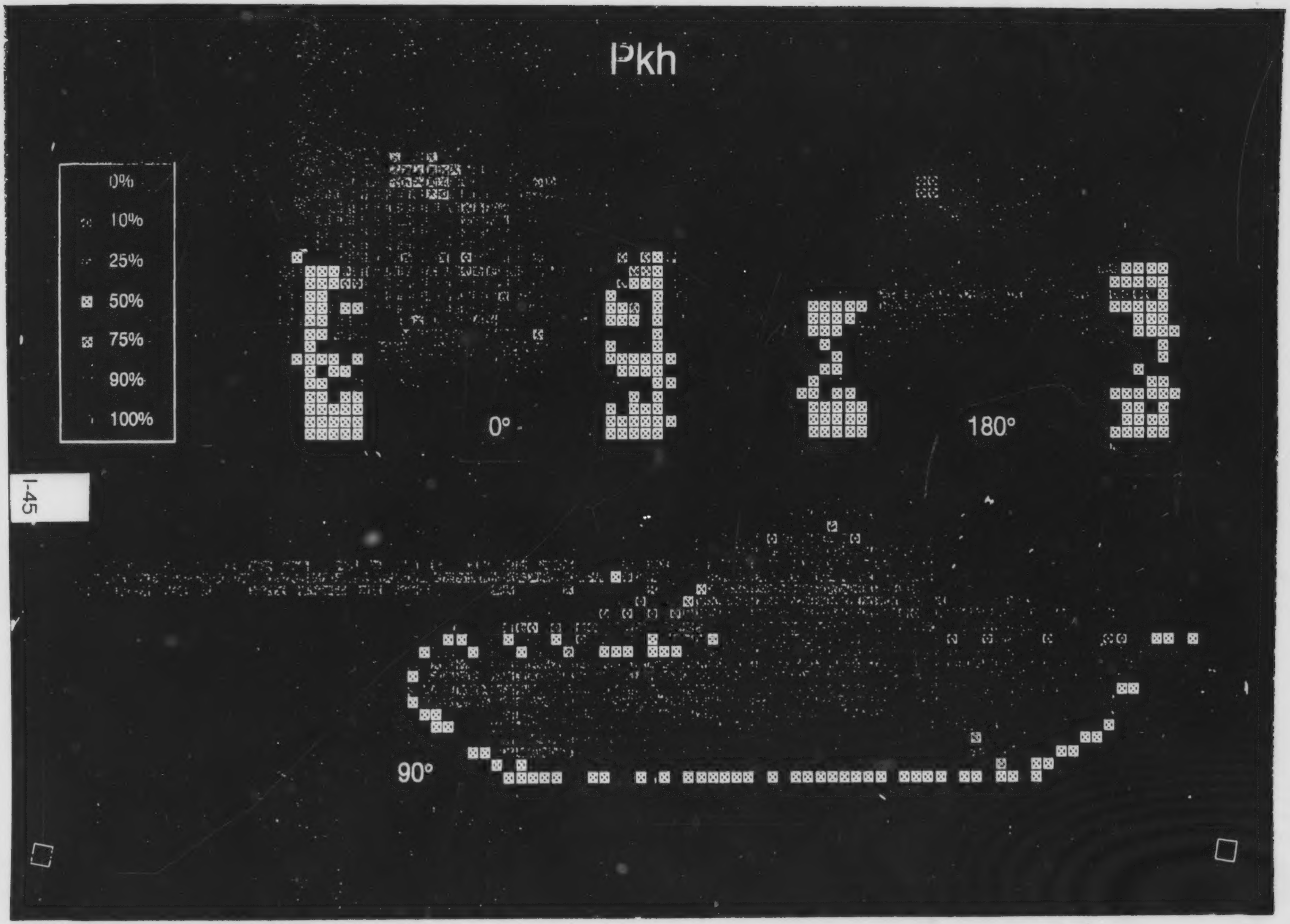




BMP-2

Target Vulnerability Model




Pkh
0%
10%
25%
50%
75%
90%
100%
0°
180°
90°

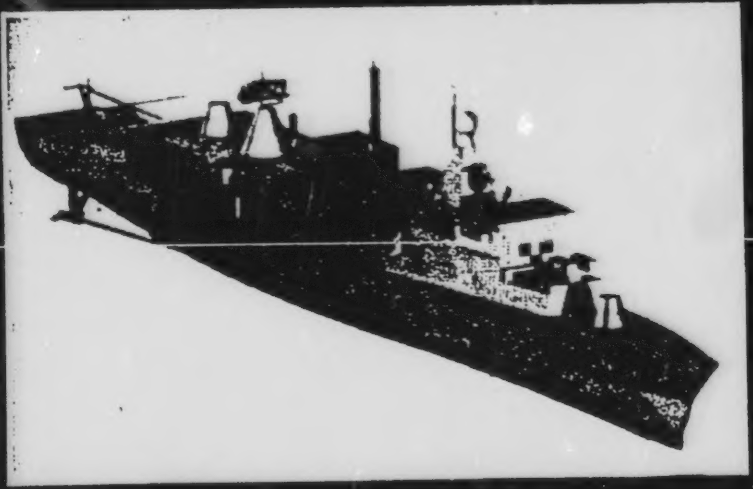
Weapon Effectiveness Group

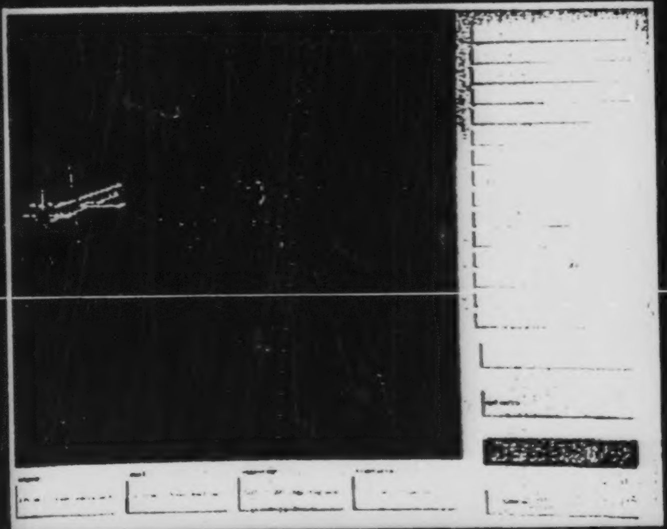
(Z.C. Verheij, M.Sc.)

Target Vulnerability

Munition Lethality

Weapon System Effectiveness





SOLDIER MODERNIZATION PROGRAMME

"towards the integrated soldier system of the future"

SYSTEM INTEGRATION

is the name of

the game

M.P.I. Manders

01-02-1995

Combat simulations at TNO

TNO-PML

- Materiel effectiveness assessment
- High level of detail
- In line with lethality / vulnerability studies
- Low level: group to company

TNO-FEL

- Force structure and deployment assessment
- Training
- High(er) level: company to brigade

TNO-TM

- Future human factors model input

Present TNO simulation models

PML

BALLS

- deterministic
- platoon to company level

BAS

- Battle Action Simulator
- stochastic
- platoon to company level

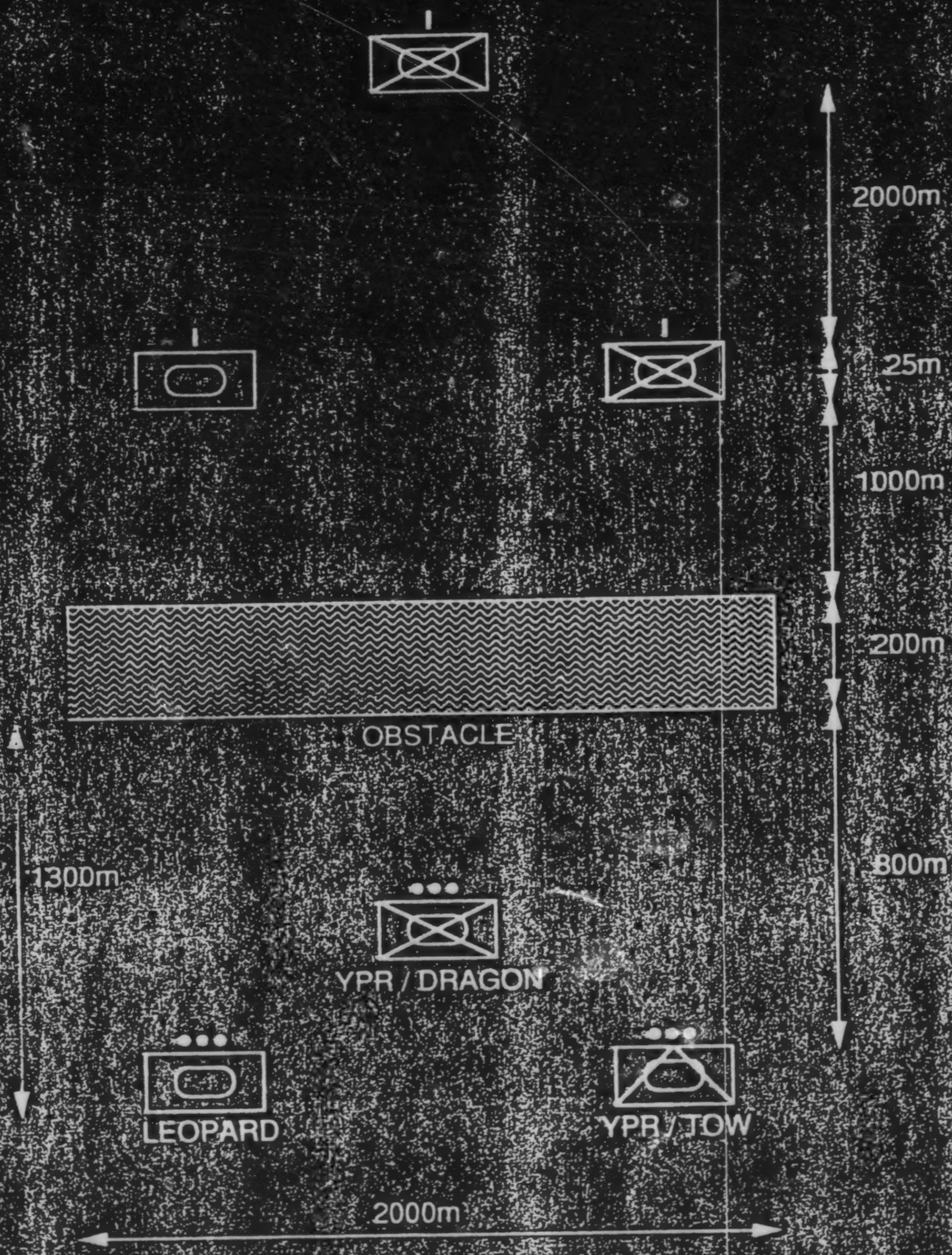
FEL

MAGIC

- deterministic
- company to brigade level

FSM

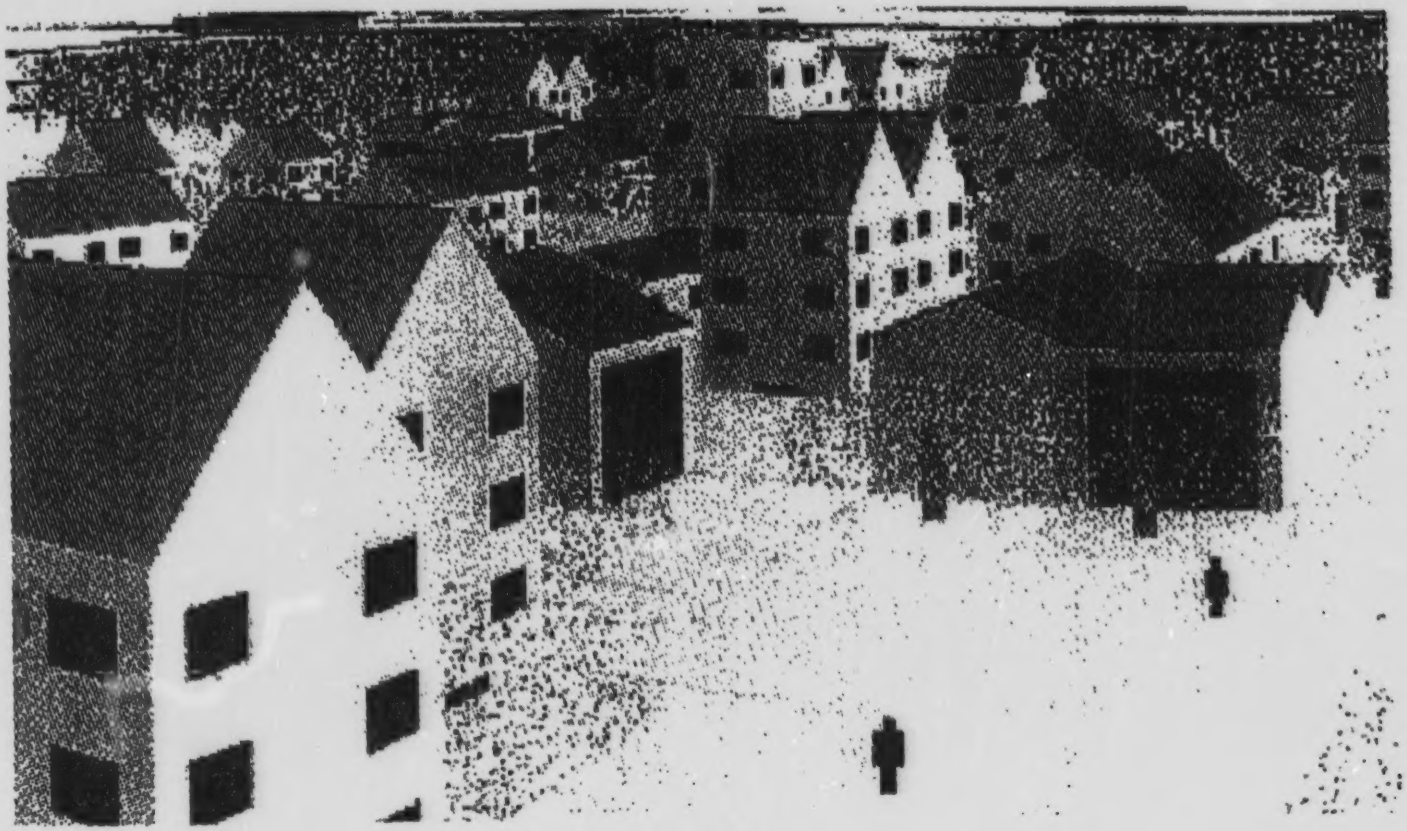
- Force Structure Model
- stochastic
- company to batallion level


2000m
25m
1000m
200m
OBSTACLE
800m
1300m
YPR / DRAGON
LEOPARD
YPR / TOW
2000m

Combat simulations 1993-1995

- **New requirements**
  - Close combat infantry actions first priority
  - Low level
  - New scenarios, e.g., urban battle
- **Participation of PML in**
  - CRISAT
  - NIAG SMP
  - WG 4
- **Conclusions**
  - Joint model development by PML and FEL (and HFRI)
  - International cooperation (CAEN, IUSS)

CAEN (Close Action ENvironment)



HUMAN SCIENCES

DERA

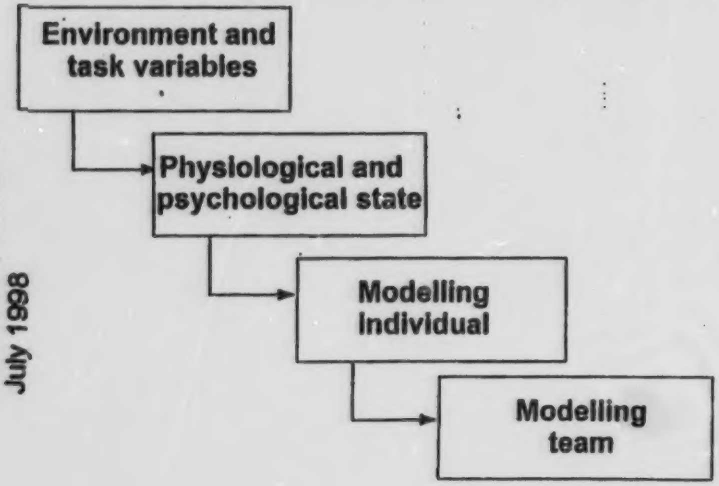
MODELLING THE SOLDIER
(THE SOLDIER DAY)

Michael Wright

Centre for Human Sciences
Farnborough, UK

DERA

Summary of current FIST modelling



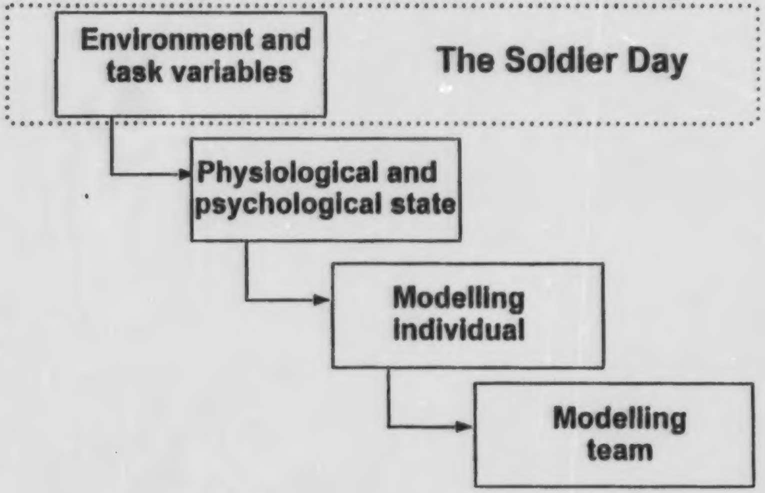
Environment and task variables

Physiological and psychological state

Modelling individual

Modelling team

Summary of current FIST modelling



Environment and task variables

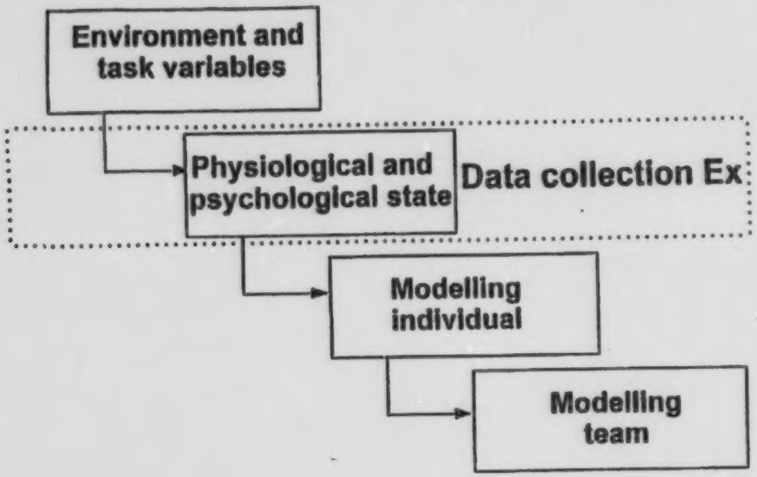
The Soldier Day

Physiological and psychological state

Modelling individual

Modelling team

Summary of current FIST modelling


Environment and task variables

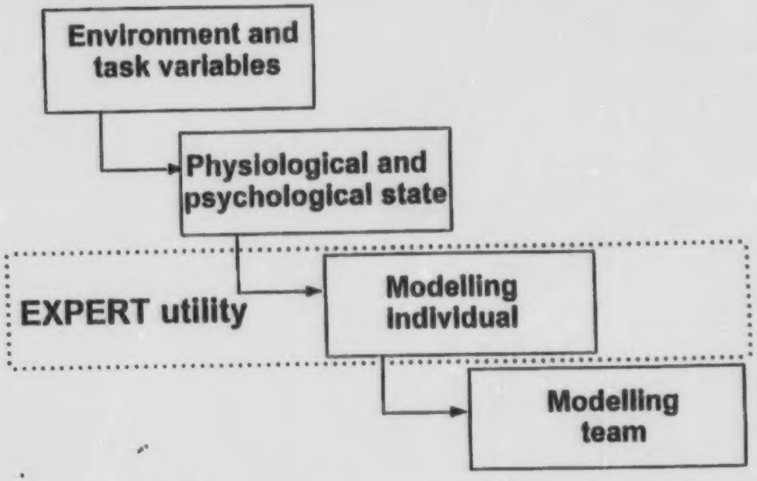
Physiological and psychological state

Data collection Ex

Modelling individual

Modelling team

Summary of current FIST modelling


Environment and task variables

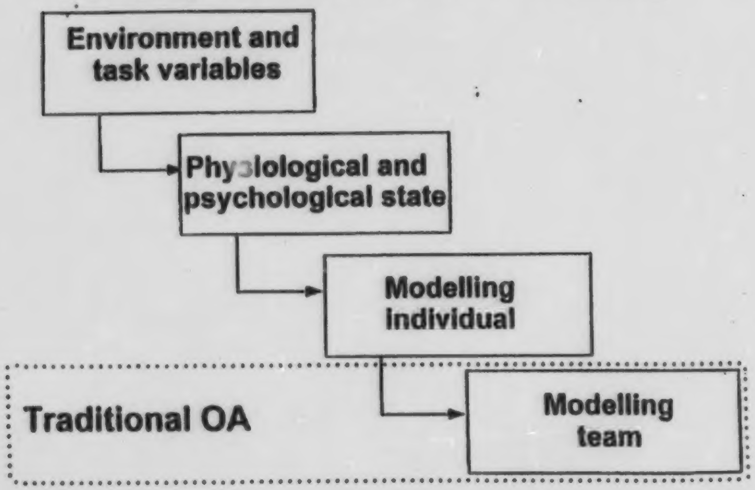
Physiological and psychological state

EXPERT utility

Modelling individual

Modelling team

Summary of current FIST modelling

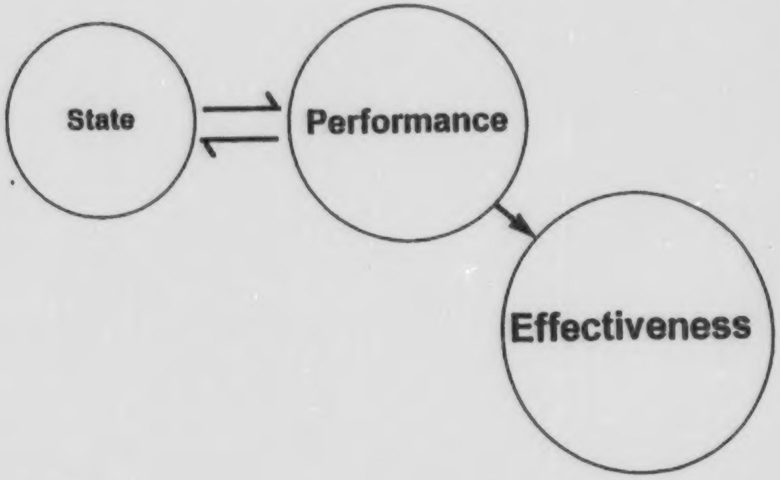

Environment and task variables

Physiological and psychological state

Modelling individual

Modelling team

Traditional OA


State

Performance

Effectiveness

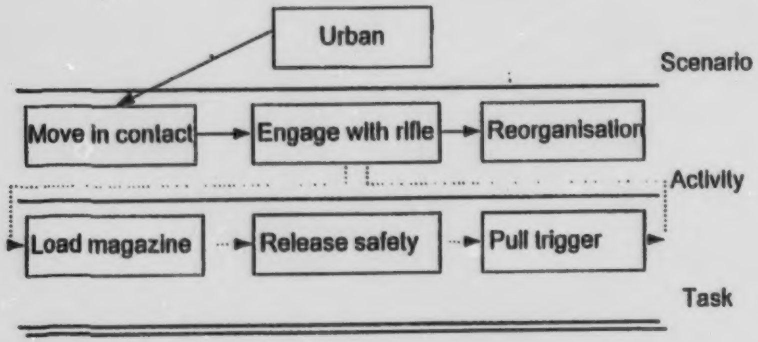
The scenarios

- 36 hour combat scenarios, each representing specific phase of war.
  (*e.g*. urban, NBC, arctic)
- Associated background information.
- Focuses on four levels of command,
  - Coy Comd, Pl Comd, Sect Comd, Rfn.
- Human Factors Task Database used to record scenario information.

The scenarios

- Attack
- Defence
- NBC
- FIBUA
- Airmobile
- Amphibious
  - (Royal Marine)
- Airfield defence
  - (RAF Regiment)
- Operations other than war
- Internal security
  - (Northern Ireland)
- Arctic
- Delaying tactics
- Jungle

Example hierarchy


Urban
Scenario
Move in contact
Engage with rifle
Reorganisation
Activity
Load magazine
Release safety
Pull trigger
Task

- Activity: Group of tasks structured together to achieve common goal.
- Task: Single discernible action.

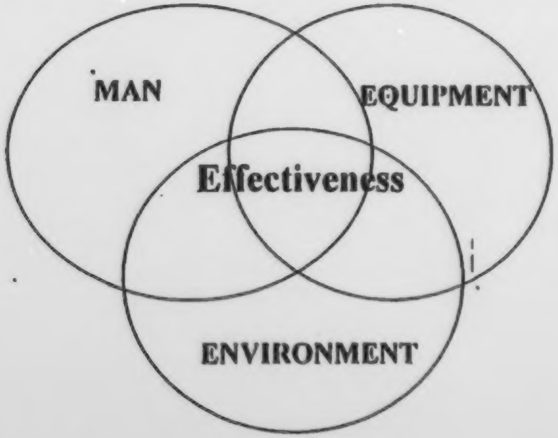
Introduction to data collection exercise

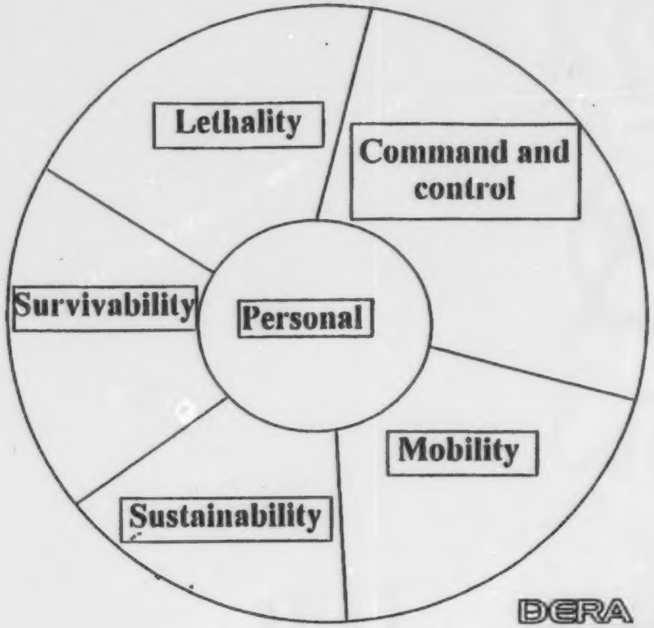
- Based around measurement of human 'state' throughout scenarios.
- Focuses on both physiological and psychological dimensions.
- Data generated for stand-alone assessment and further human modelling.
- Also provides human performance data for use in traditional operational analysis.

Performance Shaping

- Each activity has an associated time to perform or accuracy (or both).
- May be obtained from observational data or military subject matter experts (SMEs).
- Modelling exercise addresses any factors which shape this performance.
  (Performance Shaping Factors (PSFs))
- PSFs originally identified by area of occurrence but now grouped by action.

DERA


MAN
EQUIPMENT
Effectiveness
ENVIRONMENT


Lethality
Command and control
Survivability
Personal
Mobility
Sustainability

DERA

PSF categories

- Core Shaping Factors:
  - Environmental or system effects.
    e.g. climate, system feedback, load
- Task Shaping Factors:

  Specific task based effects, or 'difficulty factors'.
  e.g. ground type, battlefield noise, illumination

PSF categories (cont.)

- Individual Characteristics:

  The soldier's individual differences (traits).
  e.g. fitness, experience, baseline visual ability

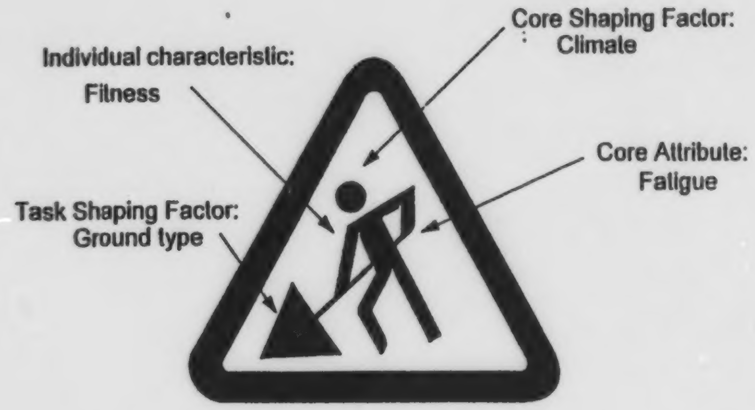
- Core Attributes:

  Current mental and physical 'states' of soldier.
  e.g. psychological stress level, fatigue, morale

The Core Attributes (states)

- Motivation *
- Confidence *
- Situation Awareness *
- Cognitive ability *
- Stress *
- Encumbrance
- Fatigue *
- Desire to sleep *
- Desire to eat
- Desire to drink
- Agility
- Dexterity *

Worked example


Core Shaping Factor:
Climate
Individual characteristic:
Fitness
Core Attribute:
Fatigue
Task Shaping Factor:
Ground type

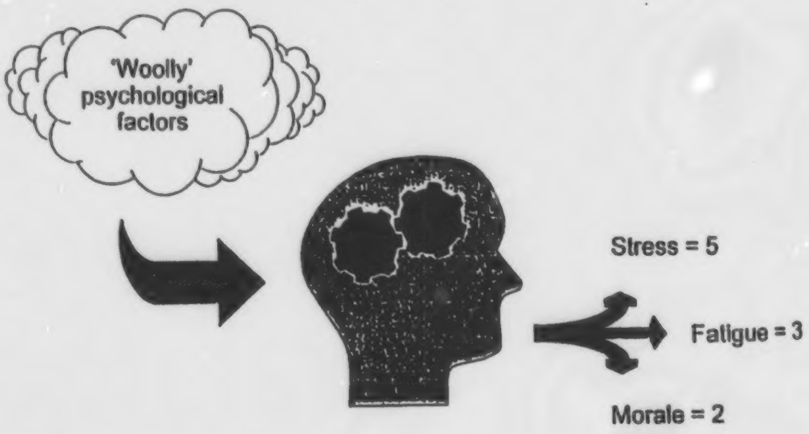
PSF scales

- Each PSF has specific definition.
- Where possible an absolute scale is used.
  (*e.g.* encumbrance measured in kg on back equivalent)
- When PSFs not measurable in this way subjective scale is used instead.
- Twelve of fifteen Core Attributes rated in this way.

Data collection exercise

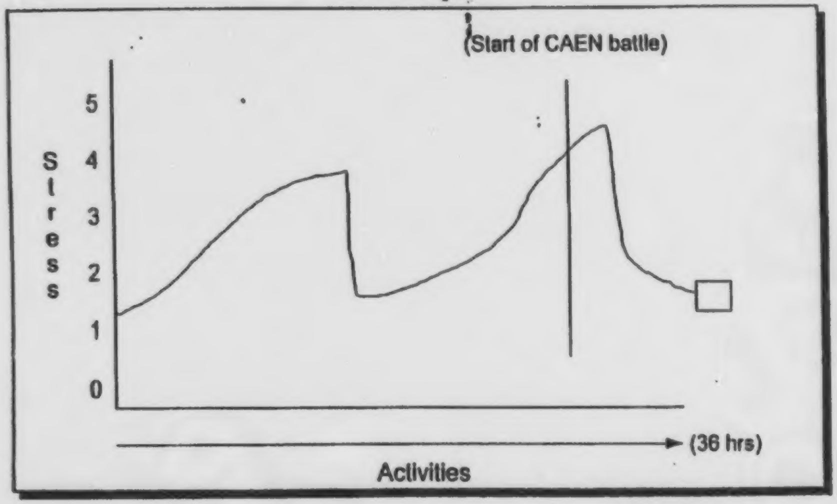
- Background explained to SMEs.
- Initial Core Attributes agreed by group discussion.
- Subsequent sessions use same start point.
- Scenario worked through one activity at a time.
- Core Attributes re-assessed by SMEs individually after every activity.

DERA


'Woolly' psychological factors
Stress = 5
Fatigue = 3
Morale = 2

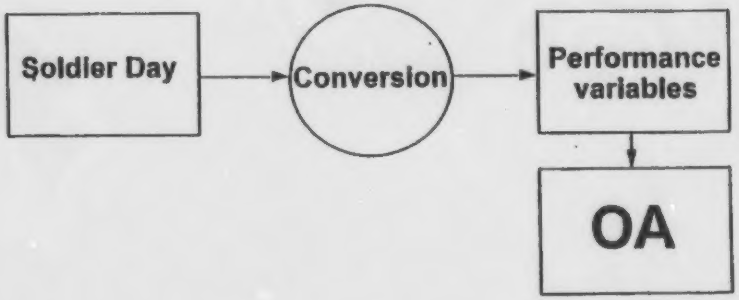
DERA

Example



DERA

Operational analysis approach


Soldier Day
Conversion
Performance variables
OA

DERA

Human factors input into OA

- Core Attributes reflect different battle histories.
- Initial performance data files can be modified according to these values.
- Three factors within CAEN likely to change: Movement speed; Firing accuracy; Suppression rate
- However, many other essential human factors cannot be manipulated.
  (*e.g* decision making, group interaction)

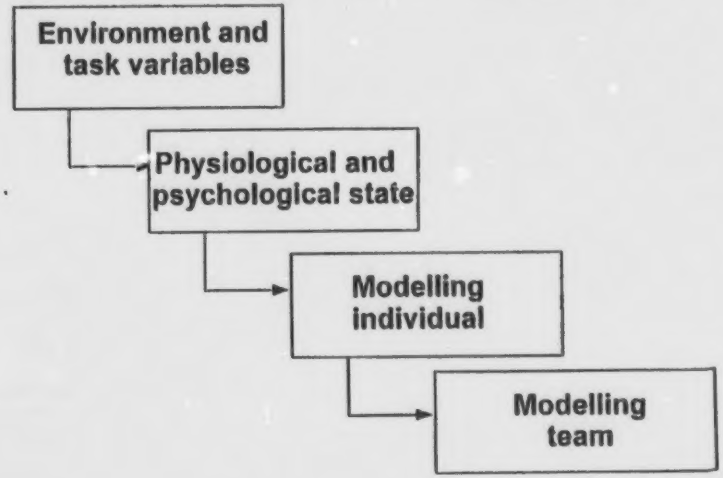
Human Performance Predictor "EXPERT"

- Excel based Performance Representation Tool.
- Tool for converting Core Attributes into CAEN performance values.
- Draws on existing literature, such as correlation between fatigue and movement speed.
- SME interpretation of data used where no exact match can be found.

Current status of modelling

- Data collection exercise conducted in Cyprus, using representative subject population (approx 50 subjects).
- Measure shown to be test / re-test reliable.
- Level of operational experience not critical.
- EXPERT being constantly updated as research progresses.
- Move towards integrated performance modelling environment where requirement for SMEs reduced.

Summary of current FIST modelling


Environment and task variables
Physiological and psychological state
Modelling individual
Modelling team

Integrated Performance Modelling Environment (IPME)

- IPME is a pan-DERA performance modelling tool developed under the corporate research programme.
- In use since November '96, with continued development planned (v1.1 due May '97).
- Loosely based around Microsaint but incorporating environment and operator models, with performance shaping factors.
- Stochastic simulation of human performance.

DERA

Definition

- IPME:

  'Provides an integrated environment for assessing the performance of individuals or small teams'.

DERA

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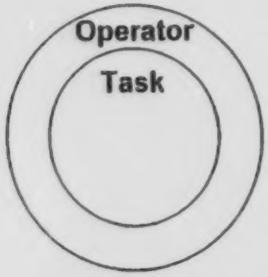
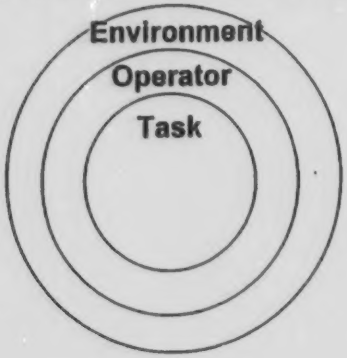


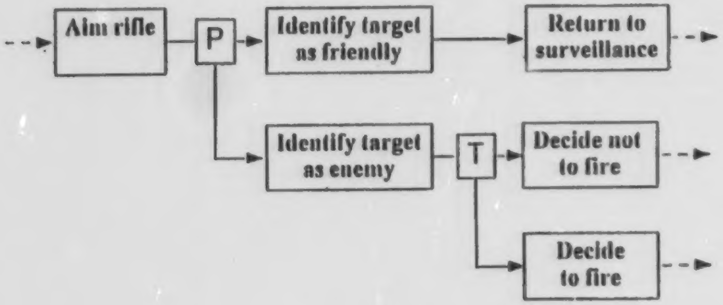
Definition

- IPME:
  'Provides an integrated environment for assessing the performance of individuals or small teams'.


Environment
Operator
Task

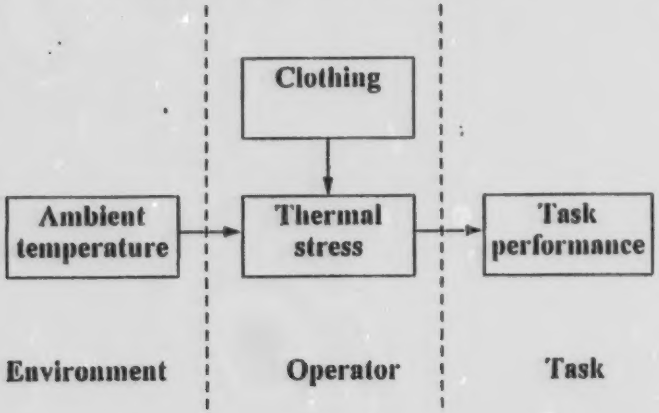
DERA

Example Task Network


Aim rifle
P
Identify target as friendly
Return to surveillance
Identify target as enemy
T
Decide not to fire
Decide to fire

DERA

Schematic representation


Clothing
Ambient temperature
Thermal stress
Task performance
Environment
Operator
Task

DERA

Uses of IPME in FIST project

- IPME can replace human subjects in calculating state based on environment and task.
- IPME can replace the EXPERT utility (calculating performance)
- IPME can be used to conduct analyses of sensitivity
  - Effect of task and environment on state
  - Effect of state on performance

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The FIST Programme

Mr. Alan Moss - FIST Technical Coordinator

DRA Fort Halstead

DERA

Format

- The FIST programme
- CRUSADER 21 / FIST Interface
- Project Management
- FIST Research
- FIST TD
- International Collaboration

DERA

FIST - The Need

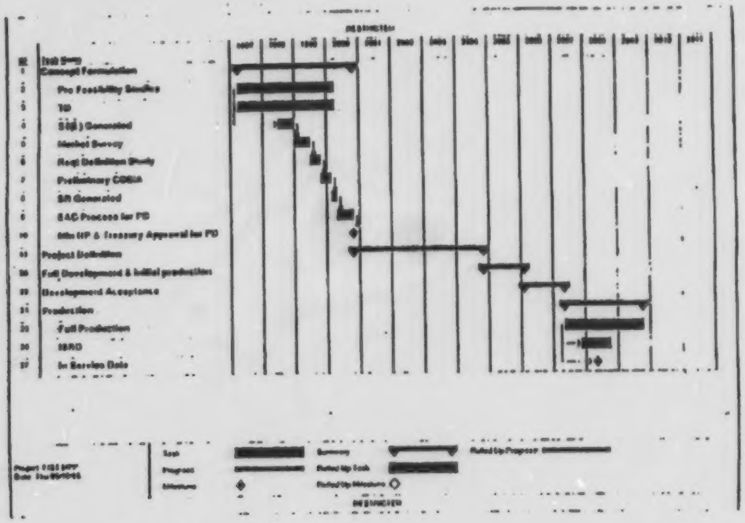
- 'To provide significant improvement in the operational effectiveness of dismounted infantry.'

DERA

FIST - The Aim

- To meet the need - *not necessarily to apply lots of modern technology to the soldier*

DERA



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Key Dates

- TD and PFS: Apr 97 - Mar 00
- ST(L): Dec 98
- SR(L): Feb 00
- PD 1&2: Jan 01 - Nov 04
- ISD: May 08

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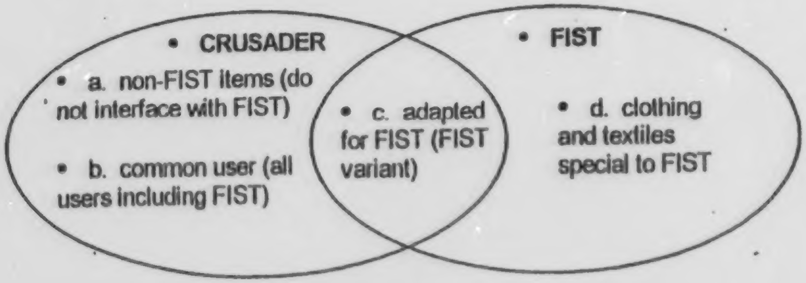
FIST - Related Projects

- BOWMAN - will provide the communications bearer for FIST
- SA80 - will provide the lethality element of FIST as part of the mid-life improvement programme
- Support Weapons - FIST must be inter-operable with the planned support weapons
- Digitisation - FIST will be linked into the Digitisation system

Two Separate but Linked Projects



- CRUSADER
  - a. non-FIST items (do not interface with FIST)
  - b. common user (all users including FIST)
- c. adapted for FIST (FIST variant)
- FIST
  - d. clothing and textiles special to FIST

Clothing and Textile Links

DERA

Two separate but linked projects:

FIST	CRUSADER 21
MGO	QMG
DDOR (Lt. Wpns. & Sim)	DCTA
AD FIST (PM Inf. Wpn. Systems)	DCTA (S & T)
DERA	

DERA

Project Management

- DDOR(Lt Wpns & Sim) to be customer for all Soldier Systems, less non-FIST clothing items
- AD FIST to be appointed to be single focus in PE (from Apr 98?)
- Interim PM Inf Wpn Systems

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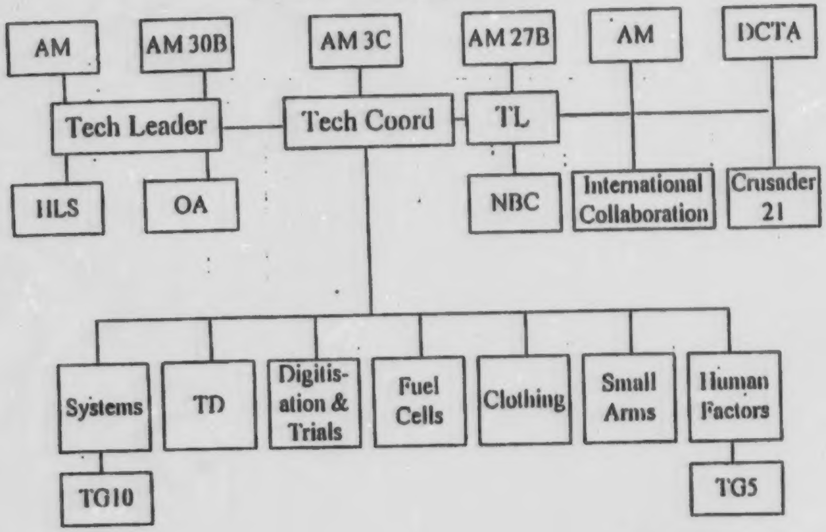
FIST Coordination


AM
AM 30B
AM 3C
AM 27B
AM
DCTA
Tech Leader
Tech Coord
TL
HLS
OA
NBC
International Collaboration
Crusader 21
Systems
TD
Digitis-ation & Trials
Fuel Cells
Clothing
Small Arms
Human Factors
TG10
TG5

DERA

FIST Research

- DERA WX6 Fort Halstead
  - Programme management and technical coordination
  - System management
  - TD Management
  - Digitisation & Trials
  - Small Arms
- DERA CHS Farnborough
  - Human Factors
- DERA CDA(L) - Fort Halstead
  - Operational Analysis
- DERA CDA (HLS) - Farnborough
  - Trials and Assessments

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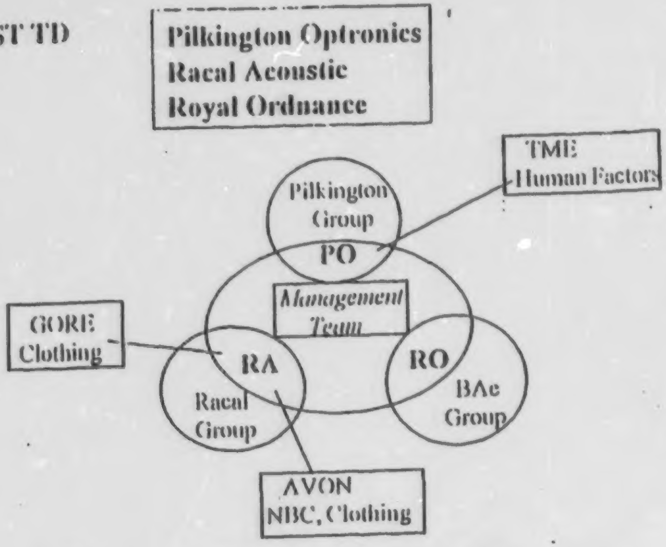
FIST Research (cont.)

- DERA CBE - Porton Down
  - NBC
- DERA Hassler
  - Fuel Cells
- DERA Malvern
  - Speech recognition, displays
- DCTA (S &T) Colchester
  - CRUSADER 21 - clothing
- HQ Inf. Warminster
  - Infantry focus

DERA

FIST TD


Pilkington Optronics
Racal Acoustic
Royal Ordnance
TME
Human Factors
Pilkington
Group
PO
Management
Team
GORE
Clothing
RA
Racal
Group
RO
BAe
Group
AVON
NBC, Clothing

The FIST-TD Industrial TEAM

FIST TD Primary Aim

- The FIST TD will address the mechanisms for meeting the Dismounted Soldier System Requirements.

FIST TD Implementation (1)

- TD will produce hardware for Concept Evaluation at the Infantry Section Level.
- TD will address subsystem Design Requirements and Constraints.
- TD will provide hardware to determine the best method for packaging the Soldier System onto the future soldier.
- TD will provide hardware to determine the best method for interfacing the Soldier System with the soldier and his senses.

FIST TD Implementation (2)

- TD will adopt a Modular Approach to the Soldier System design to enable the Soldier System functions to be configured for specific roles and functions in order to reduce the overall load carried for test purposes.
- TD will initially address and produce low quantity subsystems for evaluation.
- This will be followed by the specification and testing of a first-off Soldier System.
- This system will be tested, providing the basis for the design of the 8 systems for section level tests in the third year of the TD.

DERA

International Collaboration (1)

- Anglo French Defence Research Group (AFDRG) Working Group 14 Sub Group 04 - Soldier Modernisation

  Fr - M de Lagarde   UK - Mr Alan Moss
- The Technical Co-operation Programme (TTCP)

  Technical Liaison Group No. 8 - Soldier Modernisation

  CA - K Ackles   US - C Fitzgerald

  AUS - G Gilman   UK - A Moss

Now absorbed into the Land Systems Technical Panel, part of the Joint Systems and Analysis Group

DERA

International Collaboration (2)

- NAAG Land Group 3
  Working Group 3 - Soldier Modernisation
  UK - Lt Col Iron, R Harrison
  Other countries - US, BE, CA, FR, GE, IT, NL, TU along with AUS observers.

  Working Group 4 - Assessment and Modelling of Small Arms
  UK - D Scott, A Moss and I Mitchell
  Other countries - US, BE, FR, GE, IT, NL
- US/UK Information exchange agreements covering sensors, power sources, system integration and Human Factors

DERA

FIST Operational Analysis

- Ian Mitchell
- CDA Land, Fort Halstead
- CAEN

DERA

Content

- Update 1995-1997
- Soldier Day Snapshots: Scenarios
- Next Steps

DERA

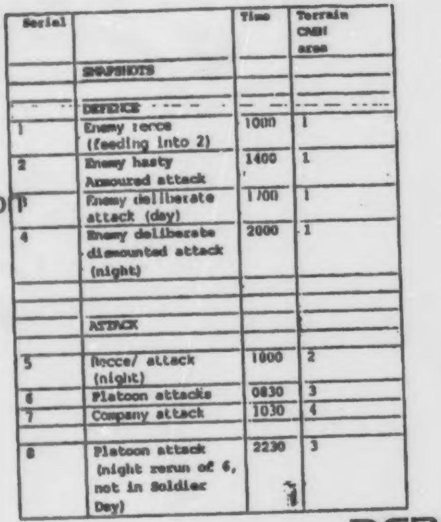
Update

- FFSS scenarios selected
  - Soldier Day combat stages
- Daylight games
  - Attrition focussed
  - Iterations
- Night Enhancements
  - Identified
  - Implemented

Update

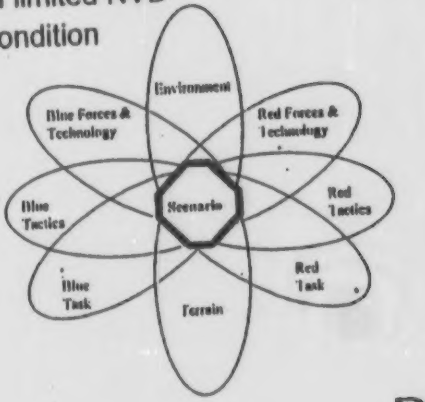
- Fog of War: Upgrades to messages
  - Delay
  - Corruption
  - Loss
- Multi Screen
  - Imperfect information flows
- Utilities
  - Quick Play Viewer
  - Transfer Utility

- Just 2 today
  - Attack
  - Defence
- 2=8=4 Solution



Serial		Time	Terrain CNBI area
	SNAPSHOTS		
	DEFENCE		
1	Enemy force (feeding into 2)	1000	1
2	Enemy hasty Armoured attack	1400	1
3	Enemy deliberate attack (day)	1700	1
4	Enemy deliberate dismounted attack (night)	2000	1
	ATTACK		
5	Recce/ attack (night)	1000	2
6	Platoon attacks	0830	3
7	Company attack	1030	4
8	Platoon attack (night rerun of 6, not in Soldier Day)	2230	3

- Mid October (15 degrees)
- Red mixed limited NVD
- Blue fair condition
- SPTA
- ......


Environment
Blue Forces & Technology
Red Forces & Technology
Blue Tactics
Scenario
Red Tactics
Blue Task
Terrain
Red Task

Aspects of scenarios in CAEN

- Terrain
- Environment
- Tasks
- Tactics
- Technology/Forces

- DTED/DFAD
- Meteorological data
- Player brief
- Doctrine Experience Judgement
- Data files
  - Weapon
  - Unit
  - Sensor

Defensive Operations

- 36 hour scenario
- Enemy Armour attacking from East to West
- Company defensive position West of Imber
- Start CO's O Group
- Recce, combat estimate, orders
- Preparation of defensive position
- Recce battle (Day)
- Enemy Mounted Quick Attack (day)
- Enemy Mounted Deliberate Attack (day)
- Enemy Dismounted Deliberate Attack (Night)

Offensive Operations

- 24 hour scenario
- Dismounted enemy holding defensive positions East of Imber
- Scenario starts with night recce of enemy position
- Combat estimate and orders
- Night march from Imber and night attack
- Reorg and receipt of orders to advance to contact
- Daylight advance 2 x platoon attacks
- Company daylight hasty attack after 14 km advance

Soldier Day Scenarios

- A Context for the combat modelling
- No guarantee of victory for Blue per script
- Importance of roles
  - Company Commander
  - Platoon Commander
  - Section (Squad) Commander
  - Private Soldier

Other Scenarios

- NBC
- FIBUA
- Airmobile
- Royal Marine
- Royal Air Force
- Operations Other Than War
- Northern Ireland
- Arctic
- Delay
- Jungle

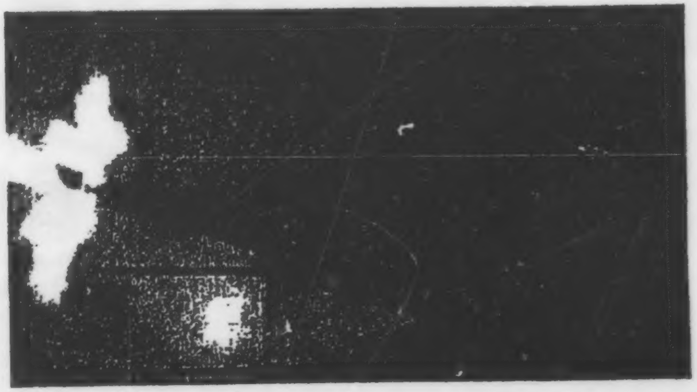
Model Test Model

- Vignettes-
  - Section level
  - Within the context of the Company Scenarios
- Advantages
  - Resources affordable for field trials
  - Verify processes modelled
  - Validate CAEN for soldier modelling

MoEs: Outputs from FIST Scenarios

- MoEs are scenario specific
  - Should reflect the aim of the mission
- Metrics are needed as quantitative yardsticks
- Performance (MoPs) and Effectiveness (MoEs) are different
- A Very Old Problem: The question of "Figures"
  - The Small Back Room (50 years ago)

OA Questions on effectiveness remain whatever the technology



The Soldier Day

Scenario background

Background: The scenario is set in NW Europe, on a piece of ground identical to that located NW of Warminster Training Centre. An enemy is moving a large force ever closer to the border of a NATO member state, under the guise of a military training exercise. The threat of aggressive action has direct implications for the security of the United Kingdom, and your unit has therefore been mobilised to protect the border of this NATO state.

Climate: It is mid October, with temperatures of about 15°C during the day, dropping to 5°C at night. There has been no rain for over a week, although there is heavy dew at dawn and a light mist rises, normally clearing by 9am. A slight breeze is blowing and there are two octas of cloud cover. The sun rises at 0600Hrs and sets at 1800. There is a half moon.

Situation enemy forces: The enemy uses the weaponry, equipment and tactics of the former Soviet Union. Their army is a mixture of conscripts and professional soldiers, and they posses a limited night vision capability. Although some enemy are harboured near the border, their main armour column is still moving forward as the scenario opens. They have sufficient supply lines although they do not posses an air power or NBC capability. It is expected that once their armour has arrived the enemy will outnumber you by three to one in your TAOR.

Situation friendly forces: You arrived in theatre approximately 2 months ago, and have been billeted in hard accommodation with electricity, showers and good sanitation. All duties such as security and catering, etc., have been taken care of by other supporting units. There has been a small outbreak of dysentery, but your company has been largely unaffected. There is no immediate threat from terrorists, insurgents or enemy air power or artillery. There are no indigenous population or refugees in your location.

Since arriving you have undertaken an intensive training programme, for which good resources of ammunition, vehicles, etc. have been made available. This has resulted in you getting four to six hours sleep a night since arrival, on a camp bed. A small number of minor casualties were experienced during training but replacements have been trickle posted to take their place. This has not caused any friction in your unit, who work well together. A full postal service is available to and from the UK. Many soldiers have mobile phones which gives you the ability to call the UK when desired. A NAAFI club has been established for the soldiers, where the 'two-can rule' applies.

You are equipped with the Combat Soldier '95 clothing ensemble, complete with body armour, which is worn when required. Assume that you fit in well with the team, and are confident of your own abilities and that of your colleagues. As the scenario open your training is over. You trust the men in your unit and feel that you are at a peak of trained efficiency.

SCENARIO 1 - DEFENSIVE OPERATIONS

INTRODUCTION

1. This scenario is based on a dismounted infantry company (A Coy), which is part of an infantry heavy battle group with one squadron of tanks. The enemy is also infantry heavy, mounted in light armoured vehicles with tank support. The scenario includes the reconnaissance and preparation of a defensive position; a standing patrol task; probing by enemy reconnaissance; 2 daylight enemy mounted attacks; a night enemy dismounted attack; and a night recce patrol.

2. The scenario extends over a period of 36 hours. Sunrise is at 0600 hours, sunset is at 1800 hours. The setting is Salisbury Plain Training Area; between Eastings 89-99, and 45-52 Northings.

COMPANY ORBAT

3. A Coy is organised with a Company HQ, 3 rifle platoons, an ATGW section of 2 firing posts, a GPMG(SF) section of 3 guns, an MFC party, and an FOO party. The rifle sections are carrying 4 x LAW 80 each.

CATEGORIES OF SOLDIER

4. A total of 9 soldiers is analysed in this scenario. They are:

a. A Coy commander.

b. 1 Pl commander.

c. Sect commander 1 (in 1 Pl).

d. Sect commander 2 (in 2 Pl).

e. Sect commander 3 (in 3 Pl).

f. ATGW operator.

g. MFC.

h. Private soldier 1 (in 1 Pl, armed with SA80).

i. Private soldier 2 (in 1 Pl, armed with LSW/CWS).

DESCRIPTION OF SCENARIO

5. At the start of the scenario the enemy are still well to the East of the River AVON, and are intending to advance West to capture WARMINSTER. There are screen forces which will impose some delay on the enemy's advance, although they will play no visible part in this scenario. The battalion plan is to construct a prepared defensive position West of IMBER, with A Coy on the left and B Coy on the right. C Sqn (a CHALLENGER squadron) is in reserve with a number of counter move options.

6. See Map 1. The scenario starts at 1400 hours with A Coy in a Concentration Area in the area of GR 914479. The OC is attending the CO's O Gp in WARMINSTER. The battlegroup is on radio silence.

7. 1400-1500 Hrs. OC A Coy returns by vehicle to the Coy Concentration Area, issues a warning order, collects his recce group, and drives to the area of the defensive position.

8. 1500-1720 Hrs. The OC carries out his recce and combat appreciation, and prepares outline orders. His O Gp moves up by vehicle to the defensive position, and the OC gives them Orders for the preparation of the defence before showing them the layout of the position. At the same time A Coy moves on foot to an RV on the defensive position.

9. 1720-1000 Hrs. See Map 2.

a. The platoon commanders meet their platoons, mark out and show the trench positions to the section commanders.

b. The sections prepare their 4 man trenches as far as possible to Stage 3. Revetment stores arrive by vehicle to the Company RV at GR 938485 at 2000 hours.

c. 1 Pl prepare their trenches to Stage 2, and then erect a wire obstacle to their flank. Wiring stores arrive by vehicle at 2300 hours. Once this obstacle is complete, they continue with their trenches to Stage 3.

d. 3 Pl prepare their trenches until the arrival of minefield stores by vehicle at 2300 hours. They then lay the Company protective minefields. Once they are complete they return to continue their trenches.

e. The tactical minefield to the front of the position is laid by engineers who have no visible part in this scenario.

f. The OC prepares and gives orders to mount a standing patrol in Imber. The patrol consists of 4 men under a section commander from 2 Pl. They deploy on foot, recce possible options, and find a standing patrol location in the roof of a building in IMBER by 2359 hours. Their orders are to give early warning of enemy movement.

g. The OC now confirms his plan of how he intends to fight the battle, including counter move options. He advises the CO on options for the use of the armoured squadron in his area. He walks round the position, giving confirmatory orders to his subordinates in each location.

10. 1000-1100 Hours. Enemy combat recce patrols pass through IMBER towards the defensive position. Their presence is reported by the standing patrol. The enemy observe the tactical minefield and are therefore aware of the presence of a defensive position. They attempt to locate the defensive positions in detail. A Coy does not open fire with direct fire, which would give away their positions, but call down indirect fire to neutralise the recce. The extent of information gained by enemy recce is dependent on the state of completion of the defensive position, in particular its camouflage.

11. 1100-1400 Hours. In this period the Company conducts routine in defence. Troops in depth positions can continue to build their defences. The Company refines its counter move plans, including route recce by the depth platoon to possible counter move options.

12. 1400-1430 Hours. See Map 3. The enemy, based on their recce reports, carry out an armoured attack off the line of march. They have very limited fire support, as the majority of their artillery and ammunition has not caught up with their forward elements. The attack is defeated by the anti-armour defence (including MILAN and LAW 80), and the enemy fail to get infantry onto the defensive position. The enemy withdraw to the area of IMBER. Enemy activity throughout this period is being reported by the standing patrol.

13. 1430-1700 Hours. The enemy prepares for a deliberate attack. A Coy restocks with anti-tank missiles and prepares for further attack. OC A Coy is informed by the CO that intelligence suggests that he is on the enemy main effort, and that he can expect another major attack before last light. C Sqn is warned that it may have to support A Coy in the forthcoming action.

14. 1700-1800 Hours. See Map 4. The enemy precedes its attack with a short but very intense artillery bombardment. The attack is mounted in battalion strength with tanks leading. Enemy attack helicopters support the initial stages of the attack. The anti-armour defence is suppressed, and the enemy succeed in getting dismounted infantry onto both forward platoons. OC A Coy requests assistance from C Sqn, who counter attack from the South. This prevents the enemy from getting further reinforcements into the forward platoon positions. Meanwhile the forward platoons are engaged in close combat with the enemy infantry in their positions. Eventually they succeed in defeating the enemy attack, taking some prisoners. The OC had warned the depth platoon to carry out a counter attack to retake one of the positions, but it proved not to be necessary and the attack was cancelled.

15. 1800-2000 Hours. A Coy arranges the CASEVAC of its casualties, and escorts the prisoners back to WARMINSTER. Damage to the defences is repaired, and ammunition is redistributed. Commanders walk round the position, checking defences and bolstering morale.

16. **2000-2100 Hours**. See Map 5. The enemy mount a deliberate dismounted attack on the position. Again the attack is preceded by intense artillery fire. They succeed on over-running 2 Pl's position, and OC A Coy orders 3 Pl to counter attack immediately and regain the position. The standing patrol reports further enemy forces moving up to continue the attack. OC A Coy realises that if these forces reach his position, then the defence will fail. He therefore orders the standing patrol to bring down fire on the enemy reinforcements. 3 Pl are successful in their counter attack after a brief period of close combat. The enemy attack loses momentum, and the survivors withdraw.

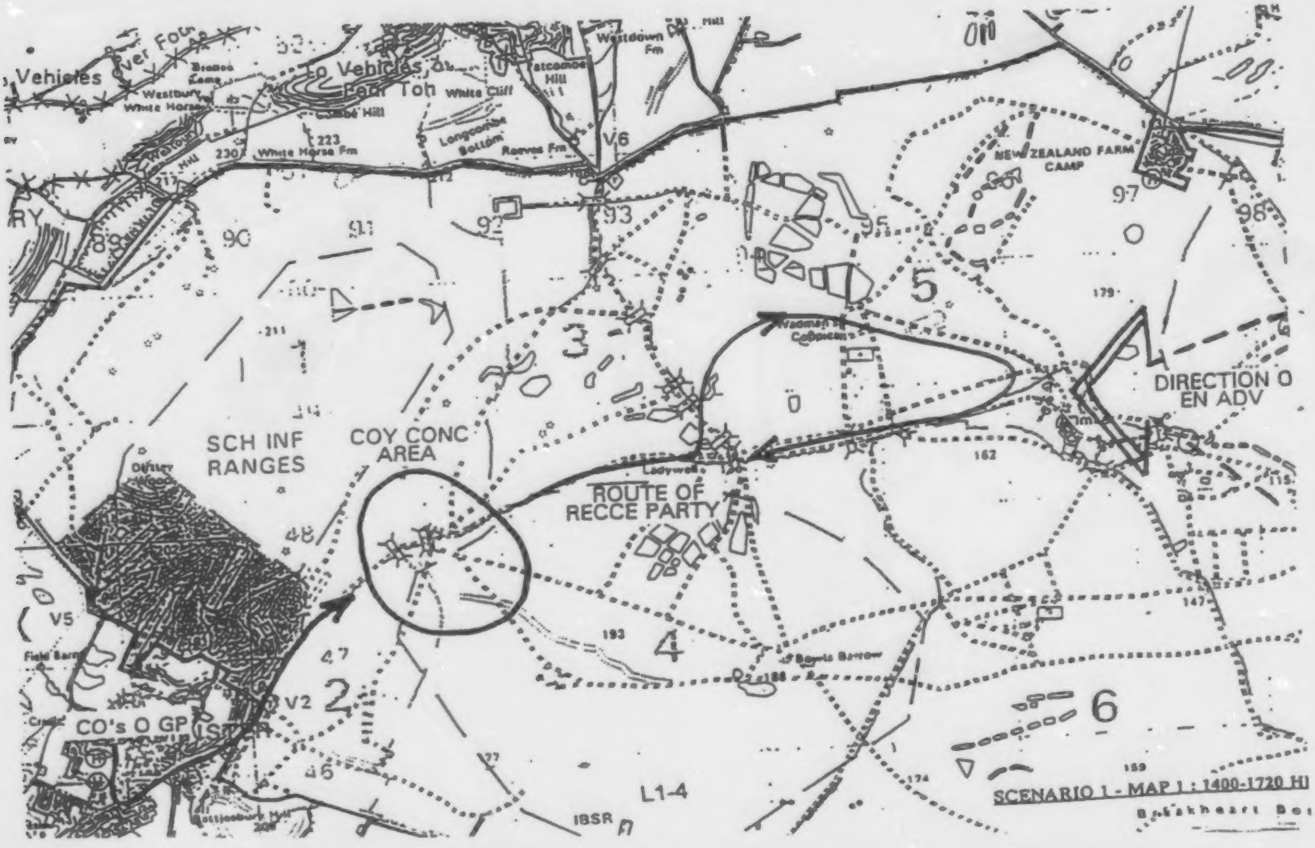
17. **2100-0200 Hours**. See Map 6. The enemy now realise that there must be a standing patrol/OP in IMBER and start systematically to look for it. OC A Coy orders the standing patrol to exfiltrate back to the Company position. He is also ordered by the CO to carry out a recce of a possible enemy HQ site at NEW ZEALAND FARM at GR 973507. He gives out patrol orders to a section commander in 3 Pl, who leads his 4 man patrol to the target. He sends his patrol report by radio, and an air attack on the target is ordered. The patrol illuminate the target with a LTM, and the target is destroyed. Meanwhile back at the defensive position, the OC reorganises the defence. 3 Pl is the only intact platoon, and they carry out CASEVAC, PW handling, ammunition resupply, and other collective admin tasks.

18. **End Of Scenario**. The scenario ends at 0200 hours with the defence stabilised, the standing patrol returned back to the position, and the recce patrol on its way back from NEW ZEALAND FARM.

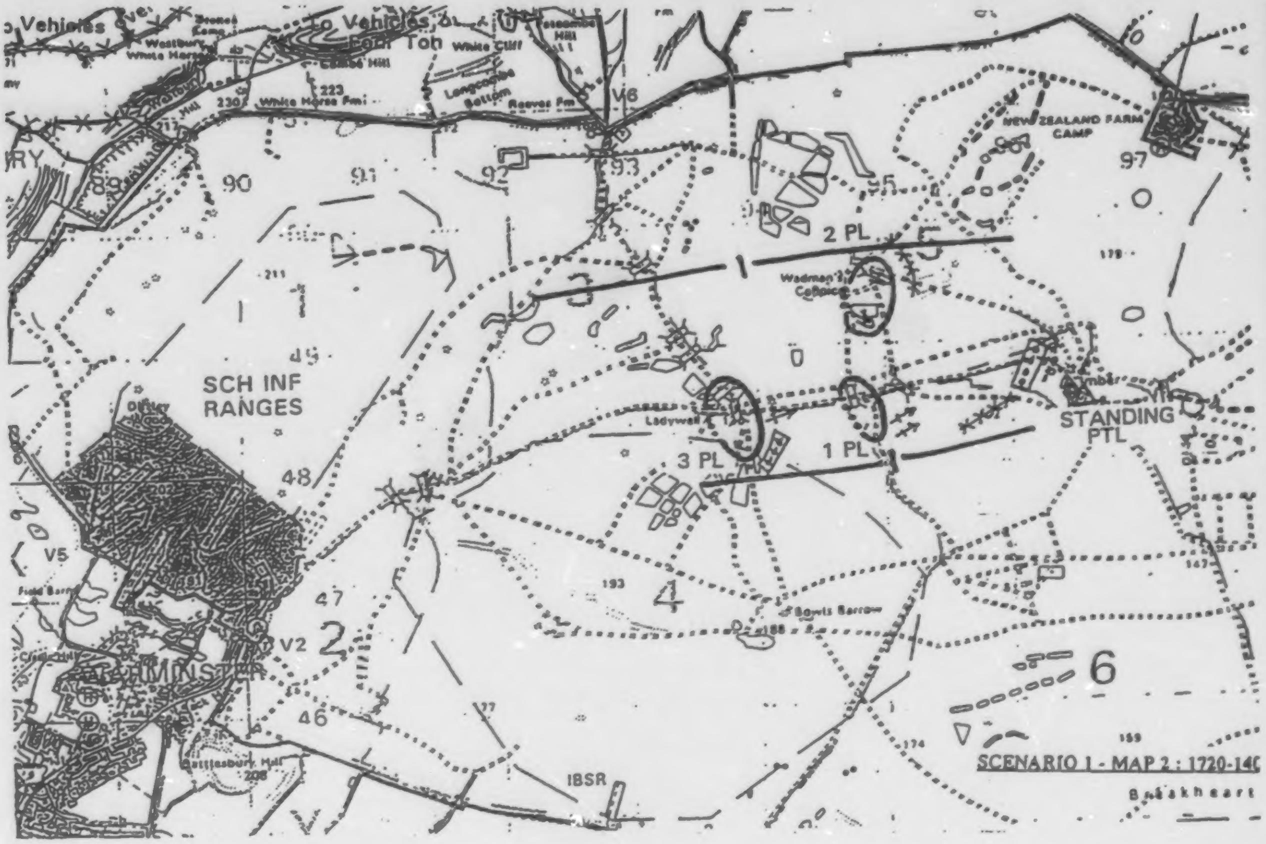
SCENARIO 1 - ACTIVITIES BY SOLDIER TYPE

Activity (a)	Coy Comd (b)	1 Pl Comd (c)	Sect Comd 1 (d)	Sect Comd 2 (e)	Sect Comd 3 (f)	Pte Sldr 1 (g)	Pte Sldr 2 (h)	MFC (i)	ATGW Op (j)
1400-1500 Receipt of BG Os. Recce party move to posn.	Receive BG Os. Map estimate, wngO. Mov by veh to def posn.	Rest/admin in Conc Area.	Rest/admin in Conc Area.	As for Sect Comd 1.	As for Sect Comd 1.	Rest/admin in Conc Area.	As for Pte 1.	Move with OC.	As for Pte 1.
1500-1720 Recce def posn. Cbt estimate, Coy Os. Coy move to def posn.	Recce posn. Cbt estimate. Prep + give Os. Show pl comds posns.	Mov by veh to def posn. Receive coy Os, + shown ground. Cbt estimate, prep Os.	March to def posn. Con sect mov fwd.	As for Sect Comd 1.	As for Sect Comd 1.	March to def posn.	As for Pte 1.	Assist OC with fire planning elms of cbt estimate. Receive Coy Os.	As for Pte 1.
1720-1000 Prep def posn, incl wiring + mining. Deploy standing ptl.	Task standing ptl. Check posns. Cfm plan. Site obstacles. Liaise BG and flanks. Develop C mov options. Rest/admin.	Give pl Os. Site trenches. Set up pl sy plan. Help dig trench. Receive cfm briefings from OC. Supervise constr of wire obs.	Receive pl Os. Give Os for trench digging. Detail sentry rosta. Dig trench. Supervise stds. Unload wire stores veh + constr wire obs.	Receive OC Os to mount standing ptl. Cbt estimate, prep + give Os. Mov on ft to IMBER. Recce + mov into standing ptl posn. Report in loc. Surv.	Receive pl Os. Give Os for trench digging. Detail sentry. Dig trench to 2300 hrs, then unload minefd stores veh, lay protective minefd. Cont trench.	Receive sect Os. Dig trench. Constr wire obs. Sentry duty.	As for Pte 1.	Estb OP posn. Build and cam trench. Develop fire plan + brief mor offr. Brief OC mor line locs + ammo avai.	Receive sect Os. Cfm arcs/armd killing areas. Dig MILAN pit. Surv.
1000-1100 Contact with en combat recce ptl.	Receive report from standing ptl + pass on. Enforce fire con Os.	Monitor en mov. Warn trenches.	Monitor en mov.	Ident en recce ptls, report.	As for Sect Comd 1.	Stand to.	As for Pte 1.	Surv and report en recce. On Os call down fire.	Monitor en mov.
1100-1400 Cont prep of posn. Routine in def.	Routine in def. Admin. Brief C mov options.	Rest/admin. Brief C mov options to pl.	Complete work. Routine in def.	Routine in loc. Surv.	Brief res C mov options, incl route recces.	Complete work. Routine in def.	As for Pte 1.	Develop fire plans to sp C moves, brief mor offr. Surv.	Surv. Routine in def.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
1400-1430 En hasty attack (mounted)	Receive contact report. Monitor situation. Give priorities for fire support.	Send sighting report. Order direct fire.	Order firing of LAW.80s when en in range.	Report on mov.	Depth pl, not in contact.	Fire LAW 80 when ordered.	Fire LSW at dismounting crews.	Call down fire, brief OC by radio.	Send sighting report. Engage en when ordered.
1430-1700 Routine in defence.	Send SITREP. Check posn/tps. Org resup.	Routine in defence. Req resup LAW80.	Org repair of posns. Alloc LAW80 resup. Routine in def.	Routine in loc. Surv.	As for Sect Comd 1.	Routine in def.	As for Pte 1.	Obsn.	Req + receive missile resup.
1700-1800 En deliberate attack (mounted)	Receive contact report. Monitor situation. Leadership. Request + coord armd sqn sp. O res pl to C attack, then cancel.	Send contact report. Order direct fire. Fight from trench. Send request for support. Leadership.	Order firing of LAW 80s against veh tgts. Close combat against en dismounting inf. Leadership Supervise 1st Aid.	Report on mov.	Res pl. Receive Os to mount C attack. Prep attack, then cancel.	Fire LAW 80 when ordered. Fire SA80 in close combat. Throw grens.	Fire LSW in close combat. Apply 1st Aid.	Call down fire, brief OC by radio.	Engage en when ordered. Mov to secondary posn. Engage en.
1800-2000 En prep dismtd attack	Arrange CASEVAC + PWs. Check tps/posns. Org ammo redistr.	As for OC.	Org repair of posns, org ammo redistr.	Report on mov.	Handle PWs. CASEVAC cas to CAP.	Repair posn. Receive ammo resup.	As for Pte 1.	Surv.	Surv. Missile resupply.
2000-2100 En deliberate dismtd attack.	Receive contact report. Monitor situation. Order C attack. Leadership. O standing ptl to bring down fire.	Send contact report. Fight from trench. Leadership.	Close combat in def. Leadership. Redistr ammo. Indicate tgts.	Report on mov. On OC Os call down fire on en forces around Imber.	Depth pl. Receive C attack Os. Lead sect to FUP. F&M in assault.	Close combat - fire SA80. Gren/bayonet fighting. Apply 1st Aid.	Close combat - fire LSW. NI obs with CWS. Gren/bayonet fighting.	Call down illum and fire. Brief OC. On Os call down C attack fire plan.	NI surv, report on mov. Close combat - fire SA80/grens.
2100-0200 Recce ptl of en posns.	Receive recce tasking from BG HQ. Carry out estimate, prep + give ptl Os. O wdr of standing ptl. Arrange ammo resup.	Routine in defence. Reorg pl. Check posns. Receive + distr ammo resup.	Routine in def. Reorg sect. Repair posns. Receive + distr ammo.	Report on attempts to find OP. Exfiltrate back to coy def posn on Os.	CASEVAC cas to CAP. Redistr ammo. Other work for CQMS.	Routine in def. Repair posns. Receive ammo resup.	As for Pte 1.	Surv	Surv.

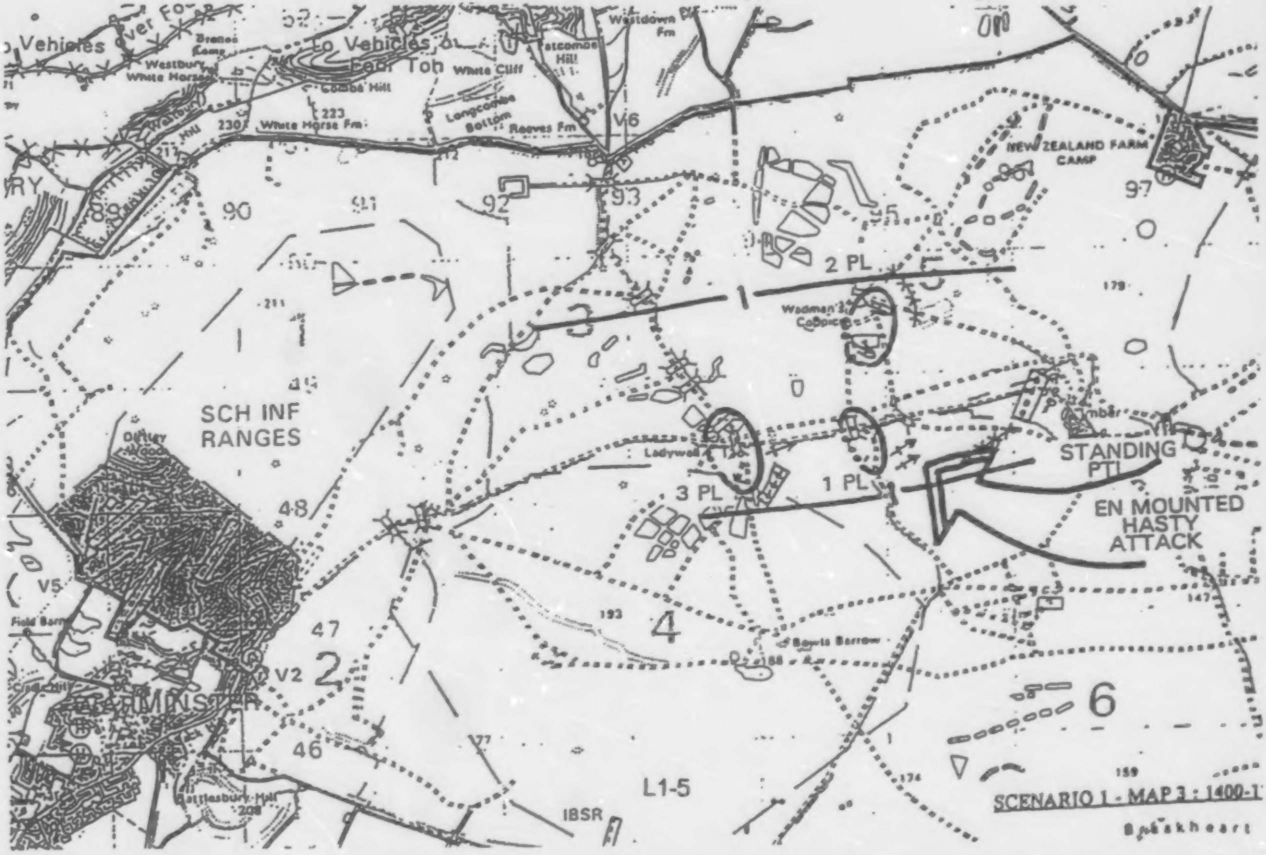

No Vehicles Over Four Ton
Bratton Camp
Westbury White Horse
White Horse Fm
Combe Hill
Longcombe Bottom
Reeves Fm
Westdown Fm
Hatcombe Hill
White Cliff
V6
NEW ZEALAND FARM CAMP
89
90
91
92
93
95
97
98
1
2
3
4
5
6
V5
V2
SCH INF RANGES
COY CONC AREA
ROUTE OF RECCE PARTY
Ladywell
Wadman's Coppice
DIRECTION OF EN ADV
CO's O GP
Field Barn
Bowls Barrow
Battlesbury Hill
IBSR
46
47
48

SCENARIO 1 - MAP 1 : 1400-1720 H



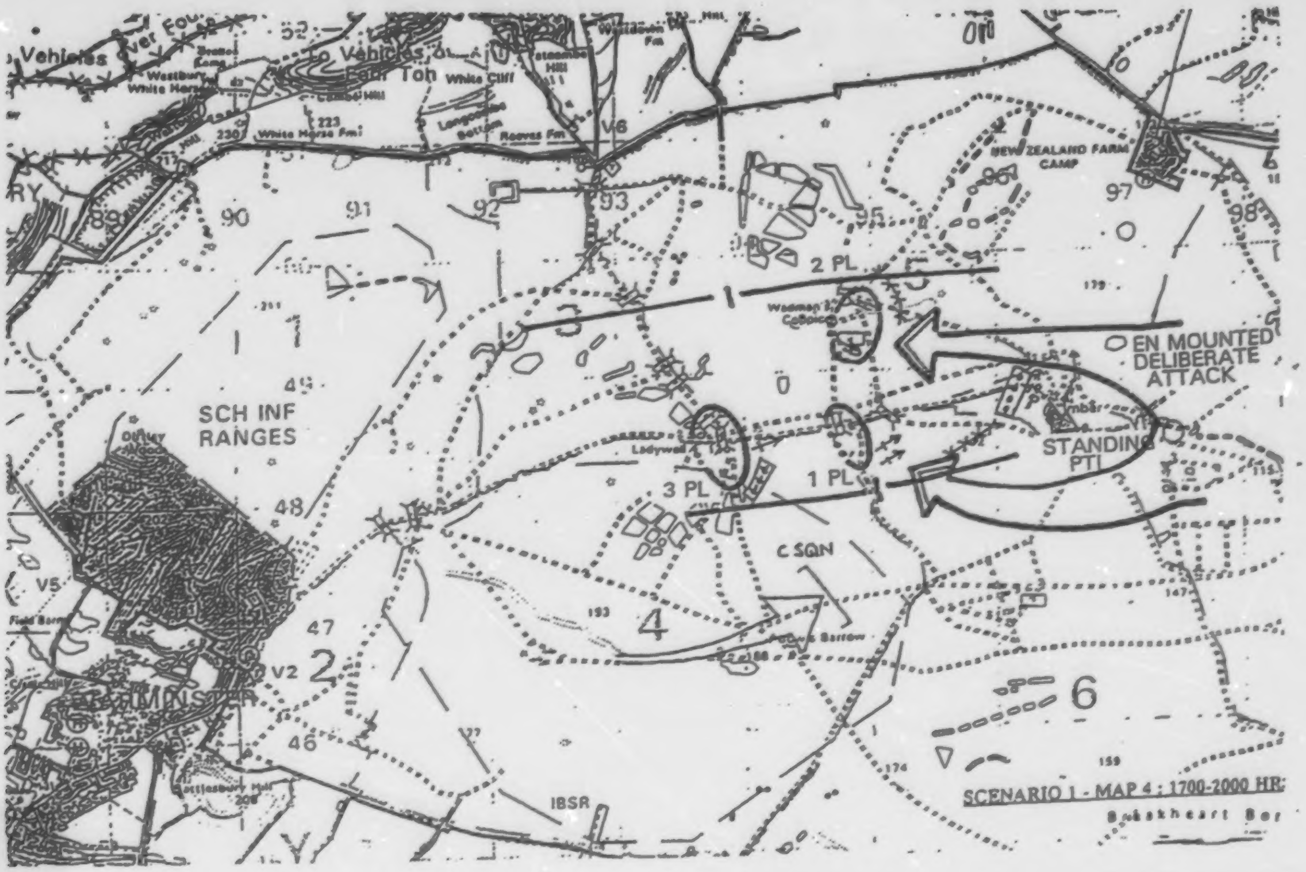
SCENARIO 1 - MAP 2 : 1720-140

Westbury White Horse
White Horse Fm
Longcombe Bottom
Reeves Fm
V6
NEW ZEALAND FARM CAMP
2 PL
Wadman's Coppice
SCH INF RANGES
Ladywell
3 PL
1 PL
STANDING PTL
V5
V2
WARMINSTER
Battlesbury Hill
Bowls Barrow
IBSR
1
2
3
4
5
6
Breakheart

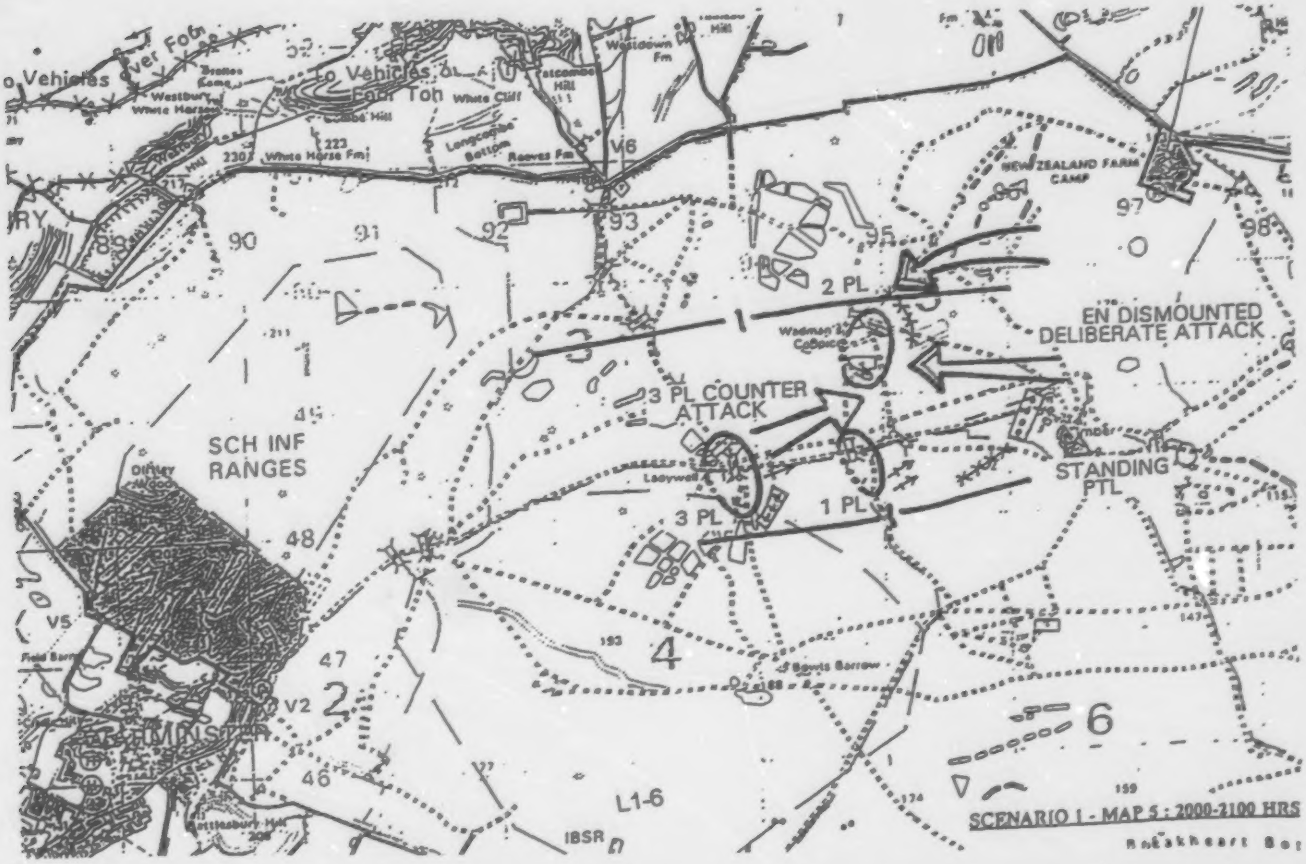


SCENARIO 1 - MAP 3 : 1400-1

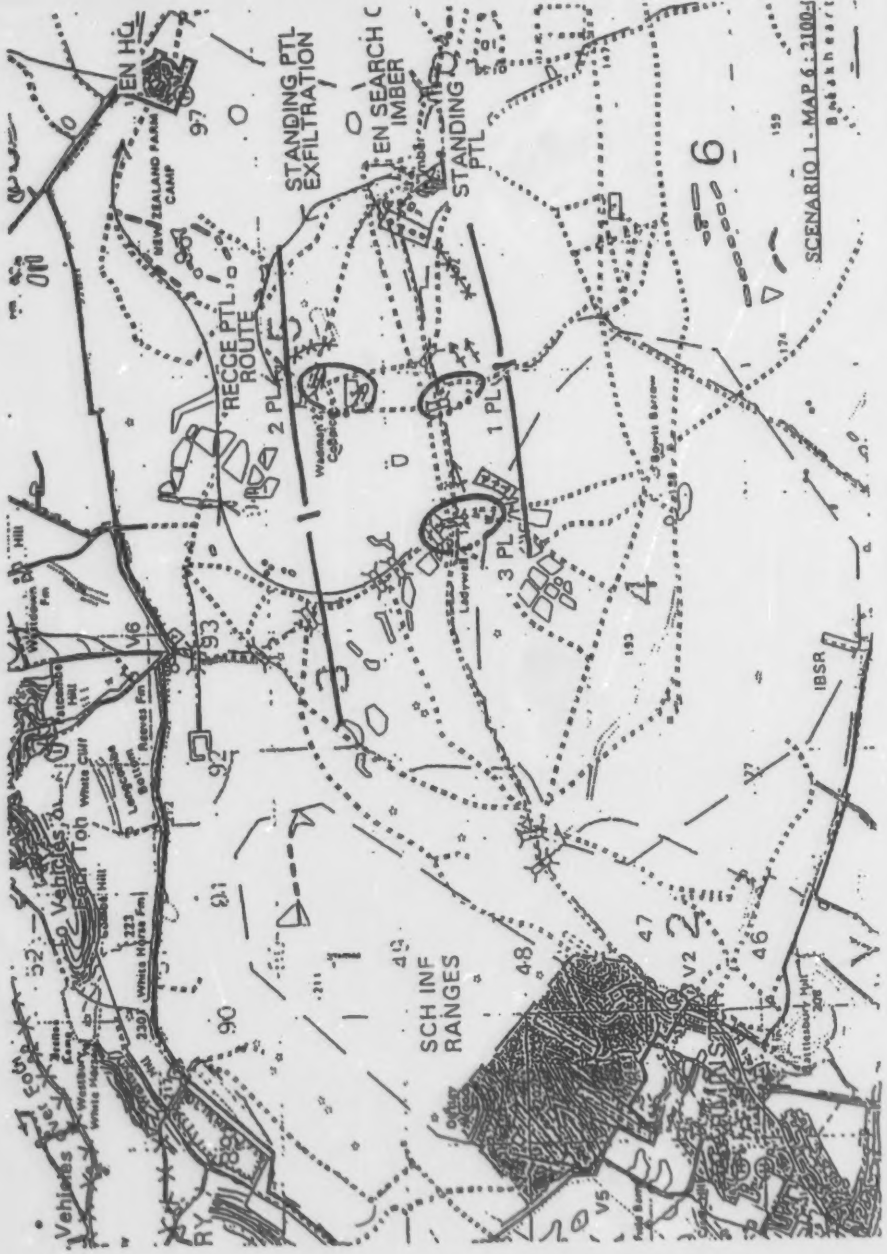
Westbury White Horse
White Horse Fm
Longcombe Bottom
Reeves Fm
V6
NEW ZEALAND FARM CAMP
2 PL
Wadman's Coppice
SCH INF RANGES
Ladywell
3 PL
1 PL
STANDING PTL
EN MOUNTED HASTY ATTACK
V5
V2
WARMINSTER
Battlesbury Hill
Bowls Barrow
IBSR
1
2
3
4
5
6
Breakheart


2 PL
EN MOUNTED DELIBERATE ATTACK
STANDING PTL
1 PL
3 PL
C SQN
SCH INF RANGES
NEW ZEALAND FARM CAMP
Wadman's Coppice
Ladywell
V6
V5
V2
IBSR
1
2
3
4
5
6
89
90
91
92
93
95
96
97
98
49
48
47
46
Westbury White Horse
White Horse Fm
Reeves Fm
Longcombe Bottom
Patcombe Hill
White Cliff
Warminster
Battlesbury Hill
Oxbury Wood
Field Barn
Breakheart Bot

SCENARIO 1 - MAP 4 : 1700-2000 HRS


2 PL
EN DISMOUNTED DELIBERATE ATTACK
3 PL COUNTER ATTACK
STANDING PTL
1 PL
3 PL
SCH INF RANGES
NEW ZEALAND FARM CAMP
Wadman's Coppice
Ladywell
V6
V5
V2
IBSR
1
2
3
4
5
6
89
90
91
92
93
95
96
97
98
49
48
47
46
Westbury White Horse
White Horse Fm
Reeves Fm
Westdown Fm
Longcombe Bottom
Patcombe Hill
White Cliff
Warminster
Battlesbury Hill
Oxbury Wood
Field Barn
Breakheart Bot

SCENARIO 1 - MAP 5 : 2000-2100 HRS


Vehicles Over Ford
Vehicles over Ford
Westbury White Horse
White Horse Fm
Longcombe Bottom
Reeves Fm
White Cliff
Westdown Fm
V6
NEW ZEALAND FARM CAMP
EN HQ
RECCE PTL ROUTE
2 PL
Wadman's Coppice
STANDING PTL EXFILTRATION
EN SEARCH C
IMBER
STANDING PTL
Ladywell
3 PL
1 PL
SCH INF RANGES
V2
V5
Bowls Barrow
IBSR
Battlesbury Hill
1
2
3
4
5
6
88
89
90
91
92
93
96
97
45
46
47
48
49
52
SCENARIO 1 - MAP 6 : 2100-
Breakheart

SCENARIO 2 - OFFENSIVE OPERATIONS

INTRODUCTION

1. This scenario is based on a dismounted infantry company, facing a largely dismounted enemy with a limited number of light armoured vehicles. The enemy uses the tactics, organisations, and equipment of the former Soviet Union. The scenario includes: a night recce patrol; a deliberate night attack; an advance to contact; two daylight hasty platoon attacks; and a daylight hasty company attack. The company also executes a forward passage of lines.

2. The scenario extends over a period of 24 hours. In that time the company moves a distance of about 28 km on foot. Sunrise is at 0600 hours, sunset is at 1800 hours. The setting is Salisbury Plain Training Area; between Eastings 90-15, and Northings 45-52.

3. Although only A Coy is represented in this scenario, it is operating within the framework of a battalion operation. There are a number of external inputs to the company from battalion HQ and the recce platoon. Liaison is also required with a flanking company for the forward passage of lines.

COMPANY ORBAT

4. A Coy is organised with a Company HQ, 3 rifle platoons, an ATGW section of 2 firing posts, a GPMG (SF) section of 3 guns, an MFC party, and an FOO party. The rifle sections are carrying 2 x LAW 80 each.

CATEGORIES OF SOLDIER

5. A total of 9 soldiers are analysed in this scenario. They are:

a. A Company commander.

b. 1 Platoon commander.

c. 2 Platoon commander.

d. Section commander (in 2 Pl).

e. Private soldier 1 (in 1 Pl, armed with LSW).

f. Private soldier 2 (in 2 Pl, armed with SA80).

g. ATGW operator.

h. MFC.

i. GPMG (SF) gunner.

DESCRIPTION OF SCENARIO

6. The enemy has been forced to withdraw to the East, and has now established a defensive position to the East of Imber. The

battalion screen force has occupied Imber, and found it to be clear of enemy. The battalion plan is to conduct 2 separate company night attacks, A Coy on the left and B Coy on the right.

7. See Map 1. The scenario starts at 1600 hours. A Coy is in a Company Concentration Area at GR 914479. The OC has already received orders to carry out a night attack, with an H Hour of 0500 hours. He has deployed to Imber Village (GR 963488), has received a brief from OC Recce Pl, and has prepared orders for his own company recce patrol. The recce patrol has moved to Imber in preparation to receive the OC's orders. The objective is an enemy platoon in a prepared defensive position at GR 991499.

8. 1600-1800 Hours. OC A Coy issues patrol orders to 1 Pl Comd, to recce the enemy position, and return by 2359 hours. 1 Pl Comd carries out his mission analysis, combat estimate, develops his plan, and gives his own patrol orders to the 4 man patrol (including Private Soldier 1). The patrol will do some short rehearsals. The OC also gives a warning order to A Coy, including a move to a Company Assembly Area West of Imber that night.

9. 1800-2359 Hours. During this period, the patrol carries out its recce task. At about 2100 hours the Company starts its night march from the Concentration Area to the Imber Assembly Area. 2 Pl Comd leads this march. See Map 2.

10. 2359-0200 Hours. The recce patrol returns, and gives its report to the OC. The OC carries out his combat estimate, develops his plan, and prepares orders. During this period he will consult with his FOO and MFC, who are also with him in Imber. The Company arrives in the Assembly Area at about 0130 hours, and the Company O Group assembles.

11. 0200-0330 Hours. OC A Coy gives his orders for the Company night attack. 1 Pl is to lead the Company into the FUP, and mark the FUP and LD. They will subsequently act as Company reserve. 2 Platoon are one of the forward assaulting platoons. GPMG(SF) and ATGW Sects are to act as fire support. The fire plan starts at H Hour, including illumination and smoke. The platoon commanders carry out their mission analyses, combat estimates, and develop their plans. They prepare and give orders to their platoons. In the meantime, the platoons will have been carrying out battle preparation under the platoon sergeants.

12. 0330-0600 Hours. See Map 3. A Coy marches to the FUP, shakes down into assault formation and crosses the LD at 0500 hours. The assault platoons cut their way through a wire obstacle, and fight their way into the enemy trench system. The fire plan suppresses the enemy and allows the assault platoons to achieve their objectives. The OC orders the reserve platoon to attack and clear a depth enemy trench position. The fire support group kills enemy attempting to escape, including 2 light armoured vehicles. The Company suffers a number of casualties who require 1st Aid and CASEVAC.

13. 0600-0830 Hours. A Coy reorganises on the captured enemy position. Orders are received from Battalion HQ to carry out an advance to contact, towards the River AVON on the 15 Easting. In order to do this, A Coy first has to move South and carry out a forward passage of lines through B Coy in the area of their objective at GR 0148. See Map 4. OC A Coy goes through the planning process, and gives orders to the platoon commanders. They in turn prepare and give orders to their platoons.

14. 0830-1100 Hours. A Coy conducts its passage of lines, and starts its advance to contact. 1 Pl is leading. See Map 5. The OC receives information from the Recce Pl that there is a small enemy stay behind party at WEST DOWN PLANTATION GR 048490. OC A Coy orders 1 Pl to conduct a hasty platoon attack.

15. 1100-1200 Hours. 1 Pl carries out its attack successfully, but on reorganisation is engaged by a depth position at GR 054490, and some casualties are suffered. Fire is called down on this position, and 2 Pl is ordered to carry out another hasty platoon attack. It achieves this successfully. During this attack enemy vehicles are seen attempting to withdraw from the area GR 058480. These are engaged by the ATGW section.

16. 1200-1500 Hours. The company continues its advance, encountering no more enemy until making contact from the area of WEXLAND HANGING GR 1148.

17. 1500-1600 Hours. OC A Coy receives the contact report, carries out a quick recce, carries out a combat estimate, and issues Quick Battle Orders (QBOs). Initially 1 Pl is to seize a preliminary objective, and once this is secure the remainder of the company will assault the main enemy position, 1 Pl providing fire support. The enemy are in a hasty defensive position, although well sited. They are supported by light armoured vehicle firing cannon from the rear. The attack succeeds once the supporting armour has been suppressed by indirect fire and ATGW.

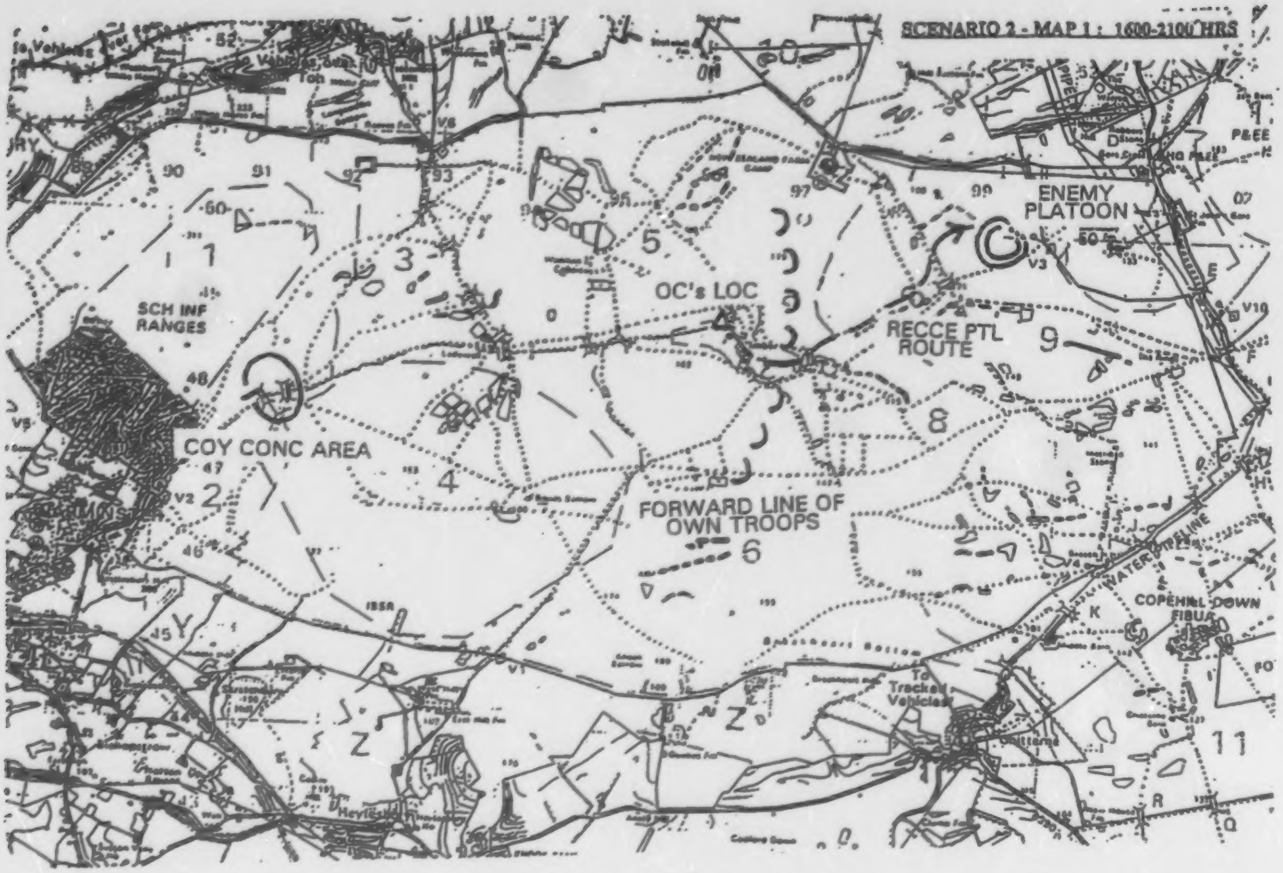
18. End of Scenario. The scenario ends at 1600 hours with the attack succeeding, and the company about to re-organise in the area of LAVINGTON FOLLY GR 1249.

(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)
0800-0830 Reorg on enemy position	Send SITREP. Receive Os, cbt estimate, prep + give Os.	Receive/send SITREPs. Check tps/arcs. Admin. Receive Os. Cbt estimate/prep Os. Give pl Os.	As for 1 Pl Comd.	Check tps/arcs. Admin. Receive pl Os. Cbt estimate, prep + give sect Os. Battle prep.	Adopt def posn. Rest/admin. Receive sect Os. Battle prep.	As for Pte Sldr 1.	As for Pte Sldr 1.	Adopt def posn. Advise OC on fire planning. Receive coy Os. Prep fire plan.	As for Pte Sldr 1.
0830-1100 Forward passage of lines. Advance to contact.	Coord passage of lines. Con mov formation. Navigation.	Con mov fmn. Navigation.	As for 1 Pl Comd.	Day move. Con sect move.	Day move.	Day move.	Day move.	Day move. Coord fire plan for passage of lines.	Day move.
1100-1200 2 x pl attacks.	Receive recce report. Order pl attacks. Send SITREPs. Coord fire sp.	Receive Os to attack. Recce. Cbt estimate. Prep and give QBOs. Coord pl hasty attack 1. Org CASEVAC. Reorg.	Move past 1 Pl contact, recce, cbt estimate, prep + give QBOs. Coord pl hasty attack 2. Reorg.	Receive pl QBOs. Issue sect QBOs. Run to FUP. Con F&M in assault. Reorg.	Run to FUP. F&M in assault. Apply 1st Aid.	Run to FUP. F&M in assault.	Adopt fire sp posn. Engage escaping enemy vehicles.	Call for and adjust fire to sp pl attacks.	Adopt fire sp posn. Engage en if poss.
1200-1500 Continue advance to contact.	Con mov formation. Send LOCSTATs. Navigation.	Con mov fmn. Navigation.	As for 1 Pl Comd.	Day move. Con sect move.	Day move.	Day move.	Day move.	Day mov	Day mov.
1500-1600 Coy hasty attack.	Receive contact report. Recce. Cbt estimate, prep + give Os. Navigate to FUP. Con attack. Send SITREPs.	Respond to contact. Brief OC. Receive Os. Brief sect comds. Seize coy prelim obj. Provide fire sp to main coy attack.	Receive Coy Os. Brief sect comds. Run to FUP. Con sects in assault. Send SITREP.	Receive pl QBOs. Brief sect. Con F&M in aslt. Send SITREP.	Receive sect briefing. Run to FUP. F&M in assault. Fire support to Coy attack.	As for Pte Sldr 1.	Receive Os. Move to fire sp base. Engage armoured targets.	Advise OC on fire sp. Attend OC Os. Fire planning. Remain with OC. Call for and adjust fire.	Receive Os. Move to fire sp base. Provide fire sp to attack.

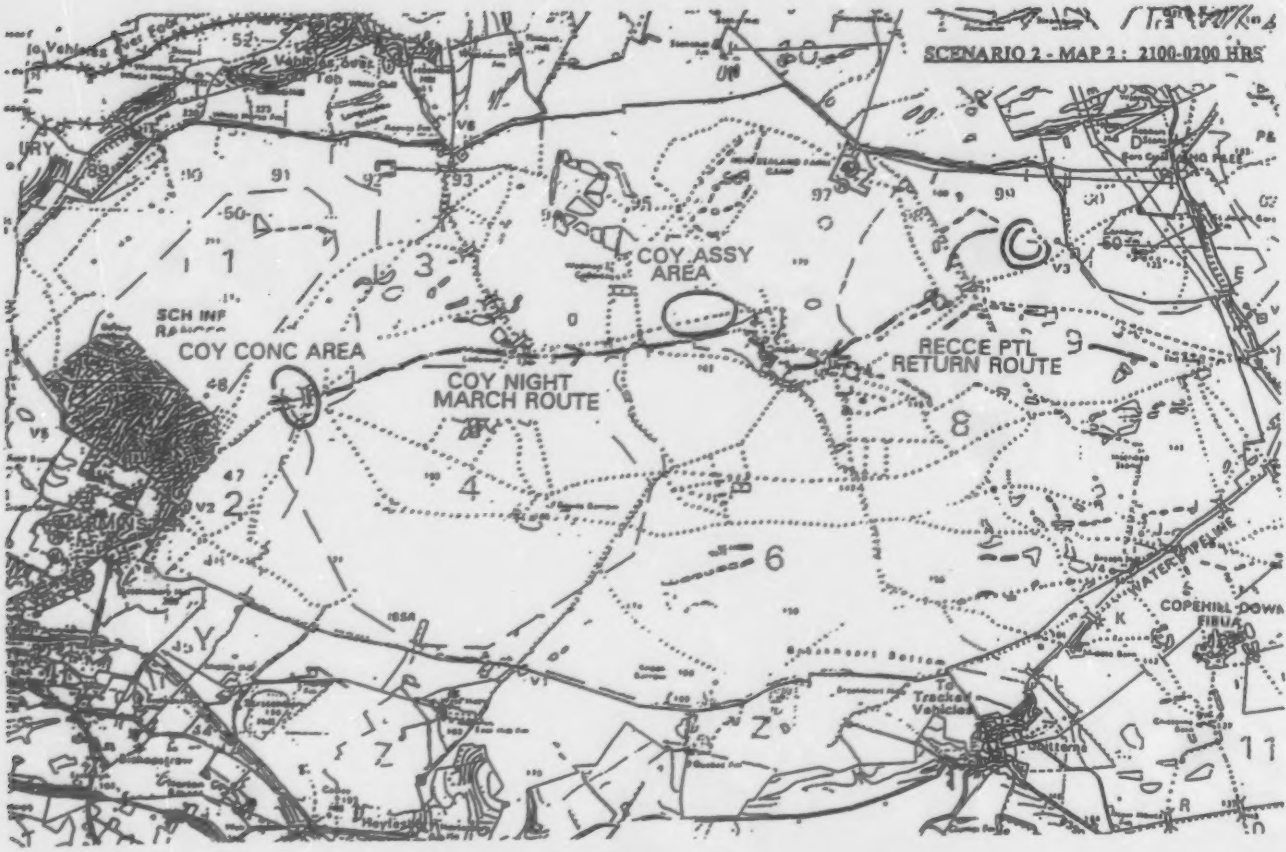
SCENARIO 2 - ACTIVITIES BY SOLDIER TYPE

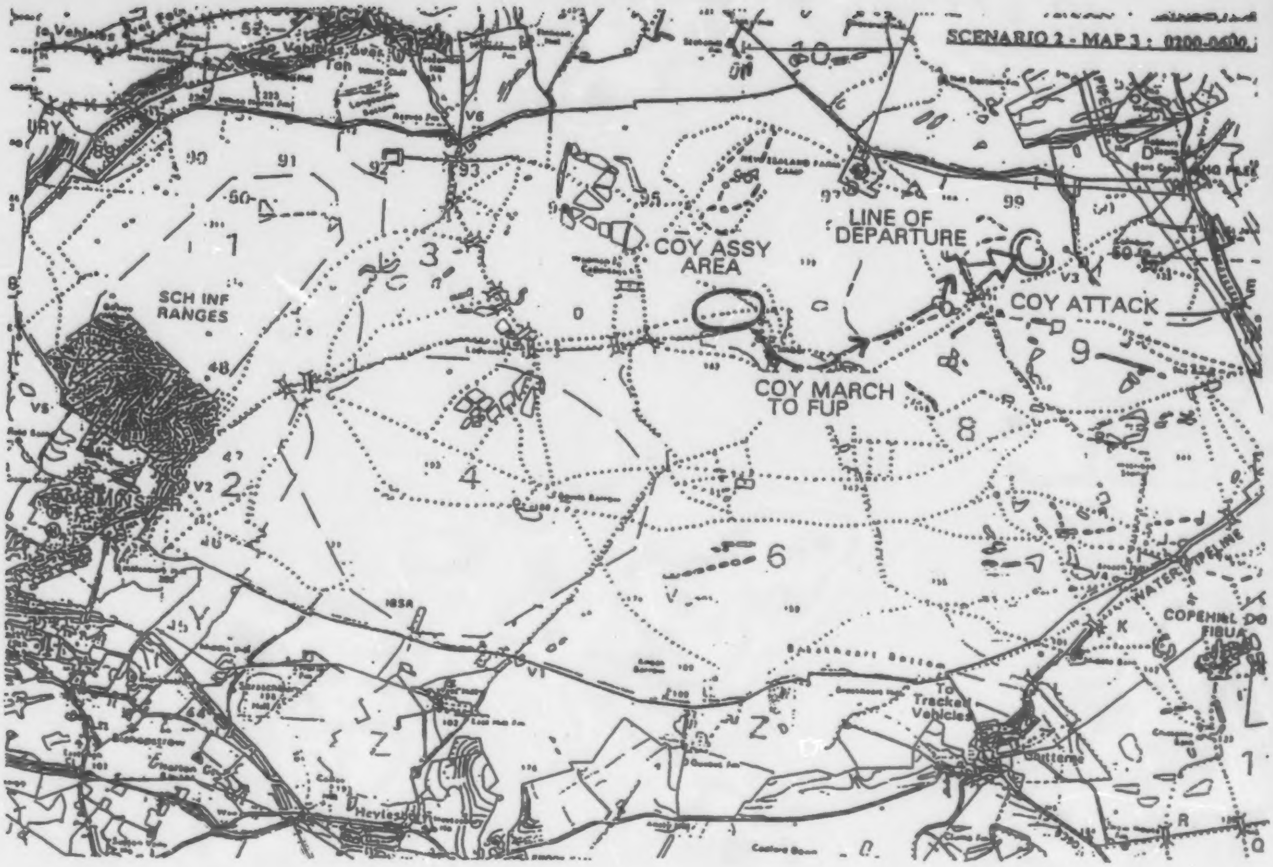
Activity (a)	Coy Comd (b)	1 Pl Comd (c)	2 Pl Comd (d)	Sect Comd (e)	Pte Sldr 1 (f)	Pte Sldr 2 (g)	ATGW Op (h)	MFC (i)	GPMG (SF) Gnr (j)
1600-1800 Battle procedure for recce ptl	Give Os for recce ptl. Wng O to Coy.	Receive Coy Os. Cbt estimate. Prep & give Os. Battle prep. Rehearsals.	Rest/admin	Rest/admin	Battle prep. Receive pl comd's ptl Os. Rehearsals.	Rest/admin.	Rest/admin	With OC. Rest/admin.	Rest/admin.
1800-2359 Recce ptl. Coy move.	Rest/admin.	Night recce ptl. Navigate and observe.	1800-2100 - rest/admin 2100-2359 - night move to Assy Area. Navigate.	1800-2100 - rest/admin 2100-2359 - night move to Assy Area.	Night recce patrol.	As for sect comd.	As for sect comd.	Rest/admin	As for sect comd.
2359-0200 Cbt estimate. Coy move.	Receive recce report. Cbt estimate. Prep Os.	Conduct ptl debrief. Give recce report to OC.	Night move. Navigate. Establish Conc Area. Check tps/arcs.	Night move. Establish Conc Area. Check tps/ arcs. Post sentries.	Recce ptl debrief. Rest/admin.	Night move into Conc Area. Sentry.	Night move into Conc Area.	Advise OC on fire planning.	As for ATGW op.
0200-0330 Battle procedure for night attack	Give Os. Liaison. Battle prep.	Receive Os. Cbt estimate, prep + give Os. Battle prep, rehearsals.	As for 1 Pl Comd.	Battle prep. Receive pl Os. Cbt estimate. Prep + give sect Os. Rehearsals.	Battle prep. Receive sect Os. Rehearsals.	As for Pte Sldr 1.	As for Pte Sldr 1.	Receive Os. Prep fire plan. Liaise fire con net. Battle prep.	As for Pte Sldr 1.
0330-0500 Move to FUP	Night move. Navigate. Identify LD + line of attack to pl comds.	Night move. Navigate. Secure and mark FUP/LD. Identify to OC.	Night move. Navigate. Orientate sect comds.	Night move. Orientate sldrs.	Night move. Assist secure + mark FUP/LD.	Night move.	Night move to fire support position.	Night move.	As for ATGW op.
0500-0600 Night attack	Initiate attack. Coord fire sp. Deploy reserve. Leadership.	Reserve pl. Attack on depth posn. Coord sects in assault. Leadership. Rep obj seized.	Direct pl onto obj. Report wire obs cut. Coord sects in assault. Leadership. Report obj seized. Org CASEVAC.	Supervise cut wire obs. Report wire cut. Coord fire team in aslt. Supervise 1st Aid. Leadership.	Res pl. Run to FUP. F&M in assault.	Cut wire obs. F&M in assault. Apply 1st Aid. CASEVAC wounded.	STA. Report enemy activity. Destroy enemy vehicles in depth.	Call for fire. Adjust fire. Advise OC.	Fire sp to coy. Report on activity.

SCENARIO 2 - MAP 1 : 1600-2100 HRS

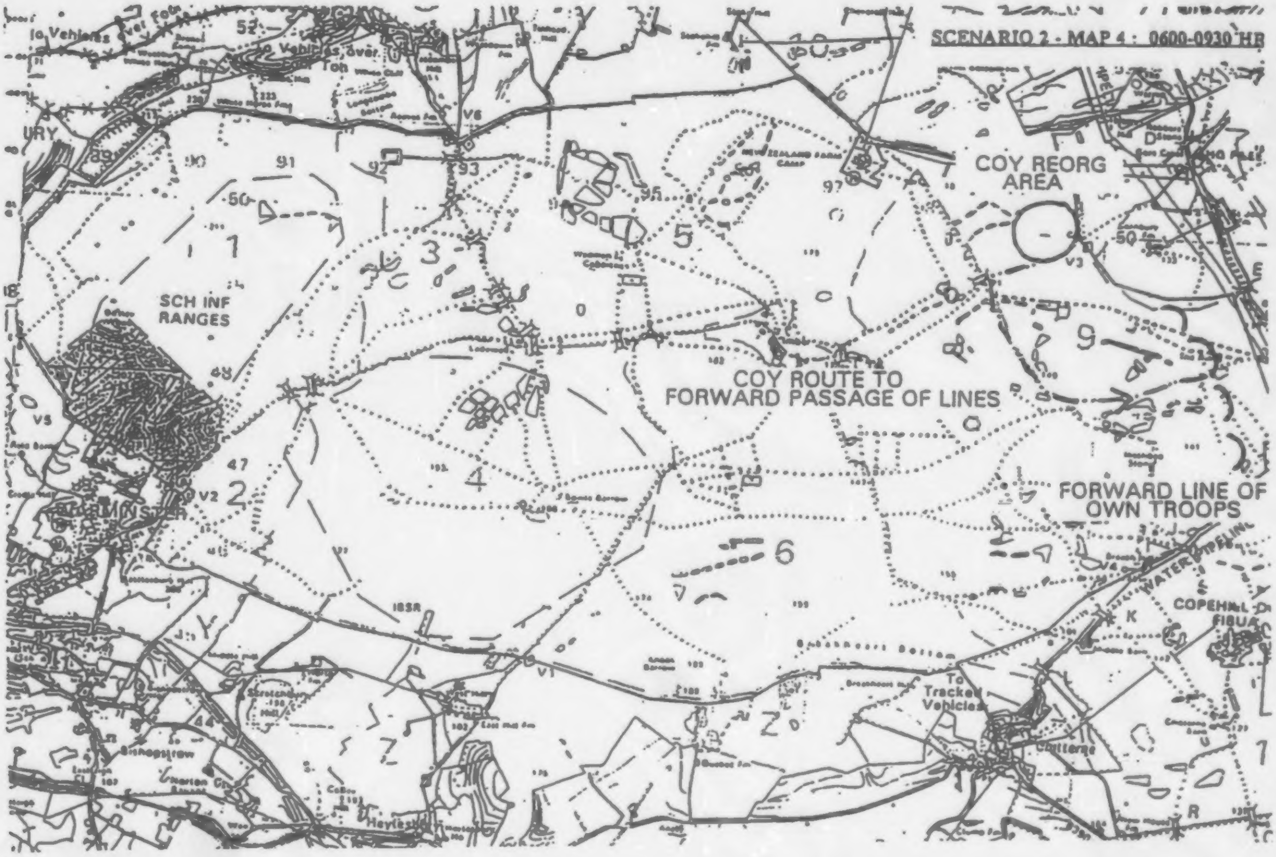

ENEMY PLATOON
OC's LOC
RECCE PTL ROUTE
SCH INF RANGES
COY CONC AREA
FORWARD LINE OF OWN TROOPS
WATER PIPELINE
COPEHILL DOWN FIBUA
To Tracked Vehicles
1
2
3
4
5
6
8
9
10
11
Y
Z
Z
90
91
92
93
97
99

SCENARIO 2 - MAP 2 : 2100-0200 HRS

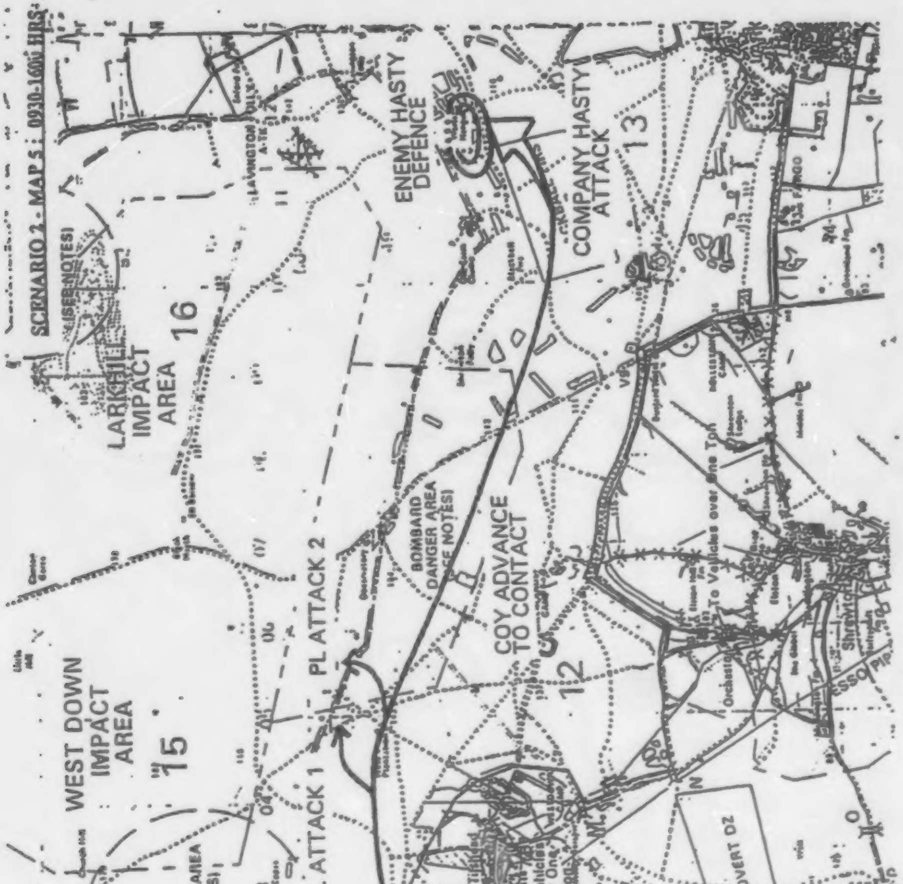

COY ASSY AREA
COY CONC AREA
COY NIGHT MARCH ROUTE
RECCE PTL RETURN ROUTE
SCH INF RANGES
WATER PIPELINE
COPEHILL DOWN FIBUA
To Tracked Vehicles
1
2
3
4
6
8
9
10
11
Y
Z
Z
90
91
92
93
97


SCENARIO 2 - MAP 3 : 0200-0600

COY ASSY AREA
LINE OF DEPARTURE
COY ATTACK
COY MARCH TO FUP
SCH INF RANGES
To Tracked Vehicles
WATER PIPELINE
COPEHILL DO
FIBUA
1
2
3
4
6
8
9
10
Y
Z
Z
V1
V2
V3
V5
V6
D
E
K
R
Q


SCENARIO 2 - MAP 4 : 0600-0930 HR

COY REORG AREA
COY ROUTE TO FORWARD PASSAGE OF LINES
FORWARD LINE OF OWN TROOPS
SCH INF RANGES
To Tracked Vehicles
WATER PIPELINE
COPEHILL D
FIBUA
1
2
3
4
5
6
8
9
10
Y
Z
Z
V1
V2
V3
V5
V6
D
E
K
R


SCENARIO 2 - MAP 5 : 0930-1600 HRS
LARKHILL IMPACT AREA (SEE NOTES)
16
WEST DOWN IMPACT AREA
15
P&EE DANGER AREA (SEE NOTES)
12
PL ATTACK 1
PL ATTACK 2
BOMBARD DANGER AREA (SEE NOTES)
COY ADVANCE TO CONTACT
12
ENEMY HASTY DEFENCE
COMPANY HASTY ATTACK
13
FOX COVERT DZ
COPEHILL DOWN
11
9
Tilshead
Orcheston
Shrewton
ESSO PIPELINE

Peter Dooley

Systems manager designate for FIST ARP

DERA WX6 Fort Halstead UK

DERA

MEASURES OF EFFECTIVENESS

- Objective of presentation

  a. to introduce some of the UK thinking on MOEs;

  b. to provide a start point for further discussions on MOEs and related aspects;

  c. to further explore areas for collaboration.

DERA

SYSTEMS PROGRAMME AIMS

- To act as the focus for capturing the requirements for soldier modernization
- To assist the OR branch in the formulation of the ST(L) for FIST
- To provide support to the COEIA for FIST
- To assist in the generation of an overall co-ordinated approach to effectiveness assessments and related issues

---

MEASURES OF EFFECTIVENESS

- Why have measures of effectiveness?
- What are measures of effectiveness?
- How are these related to military objectives and performance?
- At what level should they be measured?

Losses experienced by the blue force when red forces are in a position where they must withdraw or surrender	Achievement of objective	Engagement range?
	Loss exchange ratio	Planning time
	Time taken	Communication effectiveness
	Resource used	
	Neutral casualties	

Measure of outcome	Measures of effectiveness	Measure of performance
Ability to continue effective operations once attack has been successful	Achievement of objective	Communications functional
	Own losses	Engagement range
	Enemy losses	Situational awareness
	Resources expended	Time for battle procedure
	Time taken	

Military objective	Measures of effectiveness
Ability to continue effective operations once attack has been successful	Soldiers unavailable to continue (own losses (dead and wounded assessed separately?))
	Resources expended that cannot be made good within recovery time
	Recovery time
	Time taken

MEASURES OF EFFECTIVENESS

- Key is the definition of the outcome required of the military activity
- Relative importance of MOEs
- Relating MOEs to measures of performance

DERA

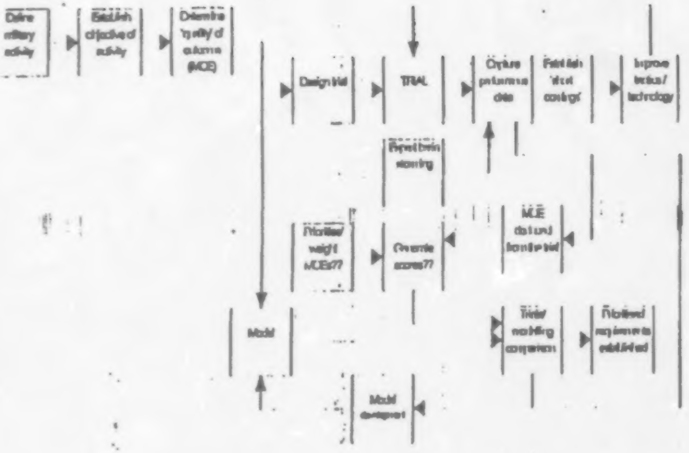
MEASURING MOE

- Use of section level vignettes
- Established following AUS visit to UK trials in July 96
- Section level:
  - a. repeatable;
  - b. relatively easy to arrange;
  - c. vignettes probably relate to most nations;
  - d. introduces scope for collaboration.

Scenario	Recce	OP	Attack	Defence	Attk Bdg	Fgt Ptl	Ambsh	Dstry LAV
Attack	✓		✓		✓		✓	✓
Defence		✓	✓	✓		✓	✓	✓
NBC	✓	✓	✓	✓				✓
FIBUA	✓		✓	✓	✓	✓	✓	✓
Airmobile	✓	✓	✓	✓	✓	✓	✓	✓
RM	✓	✓	✓	✓	✓			✓
RAF		✓	✓	✓				✓
OOTW	✓	✓		✓			✓	
NI		✓			✓	✓	✓	✓
Artic	✓	✓	✓	✓	✓	✓	✓	✓
Daisy		✓	✓	✓		✓	✓	✓
Jungle	✓	✓	✓			✓	✓	

UK FIST vignettes and scenarios

DERA


Define military activity
Establish objective of activity
Determine quality of outcome (MOE)
Design trial
TRIAL
Capture performance data
Improve tactics/ technology
Prioritise/ weight MOEs??
Generate scores??
MOE data from the trial
Model
Model development
Trials/ modelling comparison
Prioritised requirements established

SUMMARY

- MOEs for 1997 baseline & improved capability
- MOEs highly dependent on definition of objective(s)
- Level of MOEs
- Relationship between levels of MOE
- Relationship between MOE & MOP
- Weighting of MOEs - is this a good idea?
- Use of trials whilst OA tools are improved
- Use of section level vignettes
- Need to overlay command and control in section trials

COLLABORATION

- Agreement of scope of data collection?
- ?
- ?
- ?

SOLDIER SYSTEM MODELING

U.S. Soldier System Modeling
Assessment & Challenges

Dale Malabarba

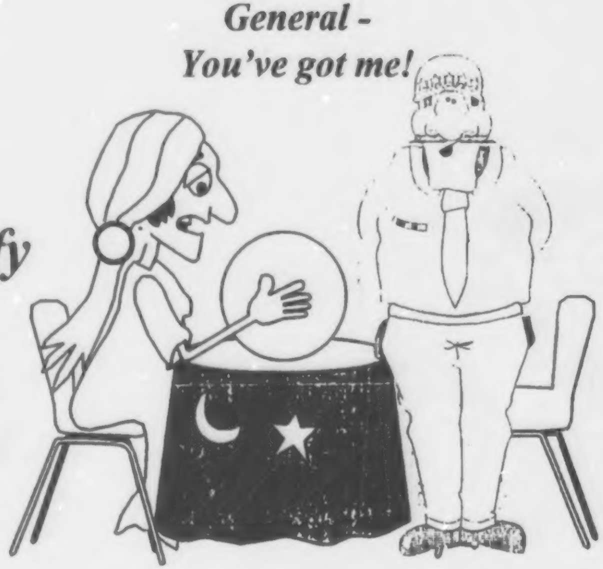
Chief, Advanced Concepts Division

U.S. Army Soldier Systems Command

SOLDIER SYSTEM MODELING

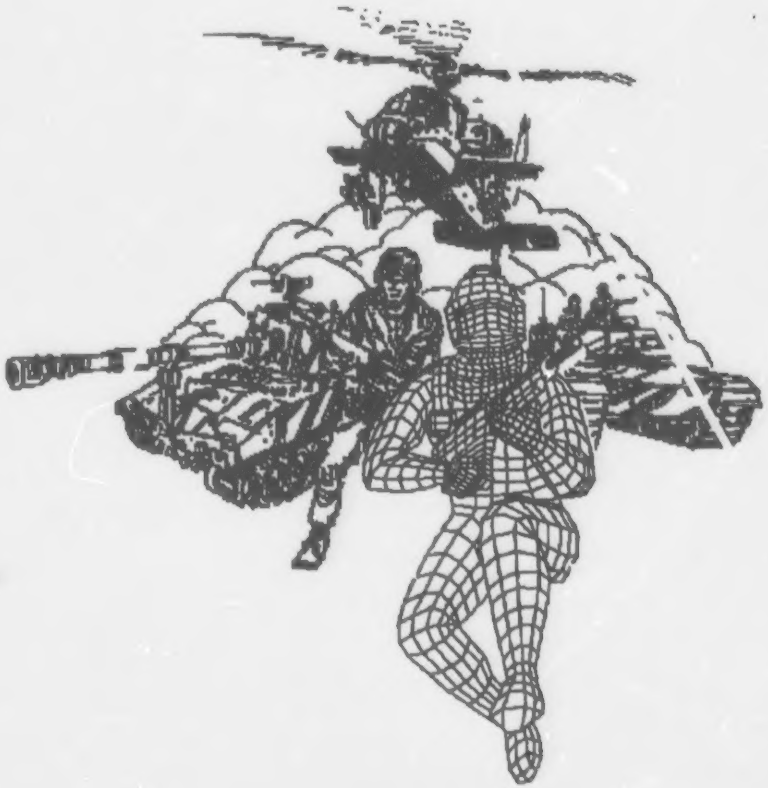
WHY SIMULATION ?

Simulation (Exercises, Training, Operations, and Planning) is the most cost effective peacetime method to develop requirements, explore doctrine, and quantify soldier systems' performance -- allowing examination of the full range of battlefield operations and hazards



EVERYTHING BUT WAR IS SIMULATION

Virtual
(Apparently Real)



Subsistent
(Real, Live)

Constructive
(Combat Model)

SOLDIER SYSTEM MODELING

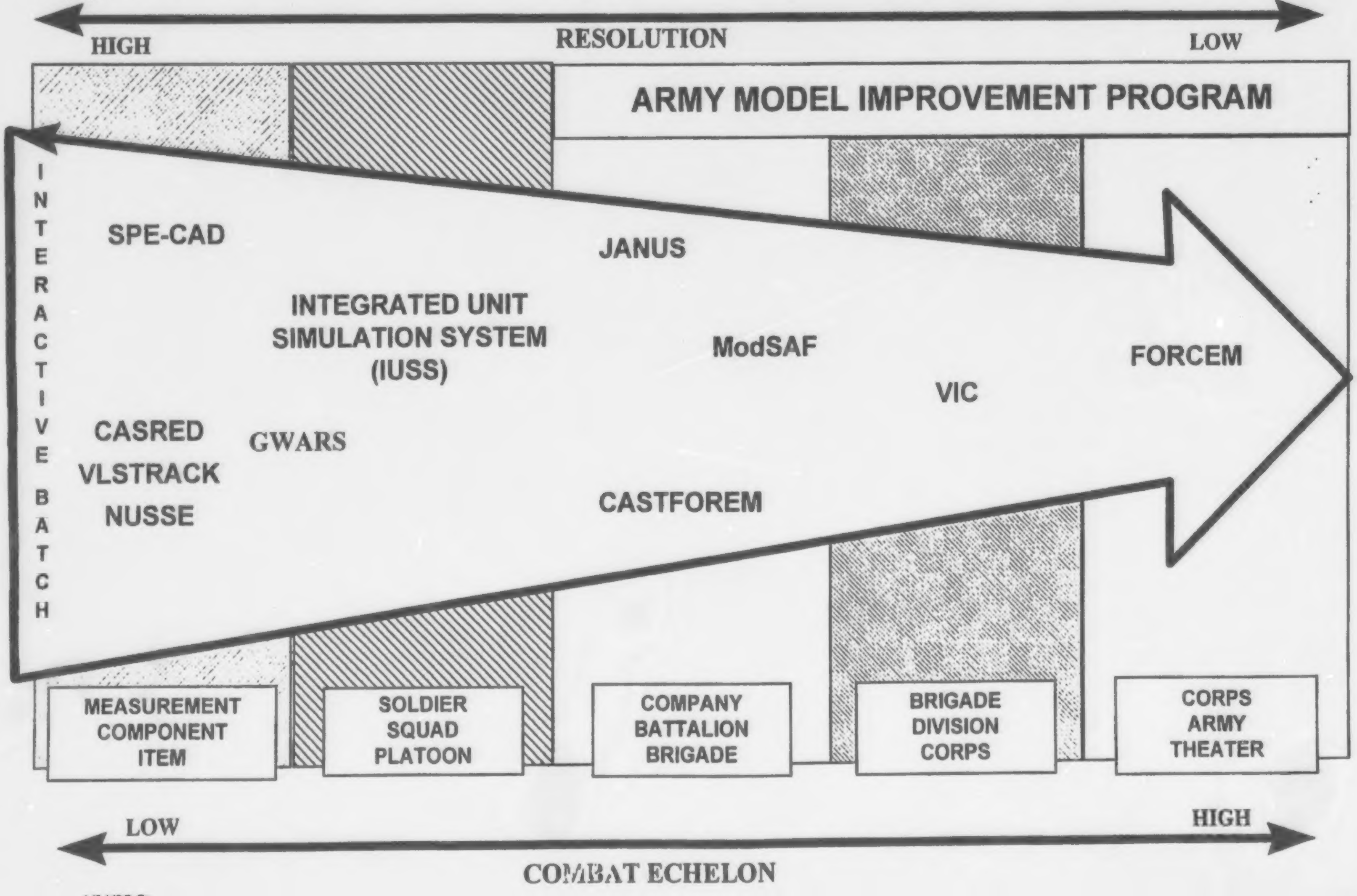
US DISTRIBUTED SIMULATION DOMAINS

- *__Advanced Concepts and Requirements (ACR):__* ***Includes combat development, doctrine development, experimentation, and requirements generation.***

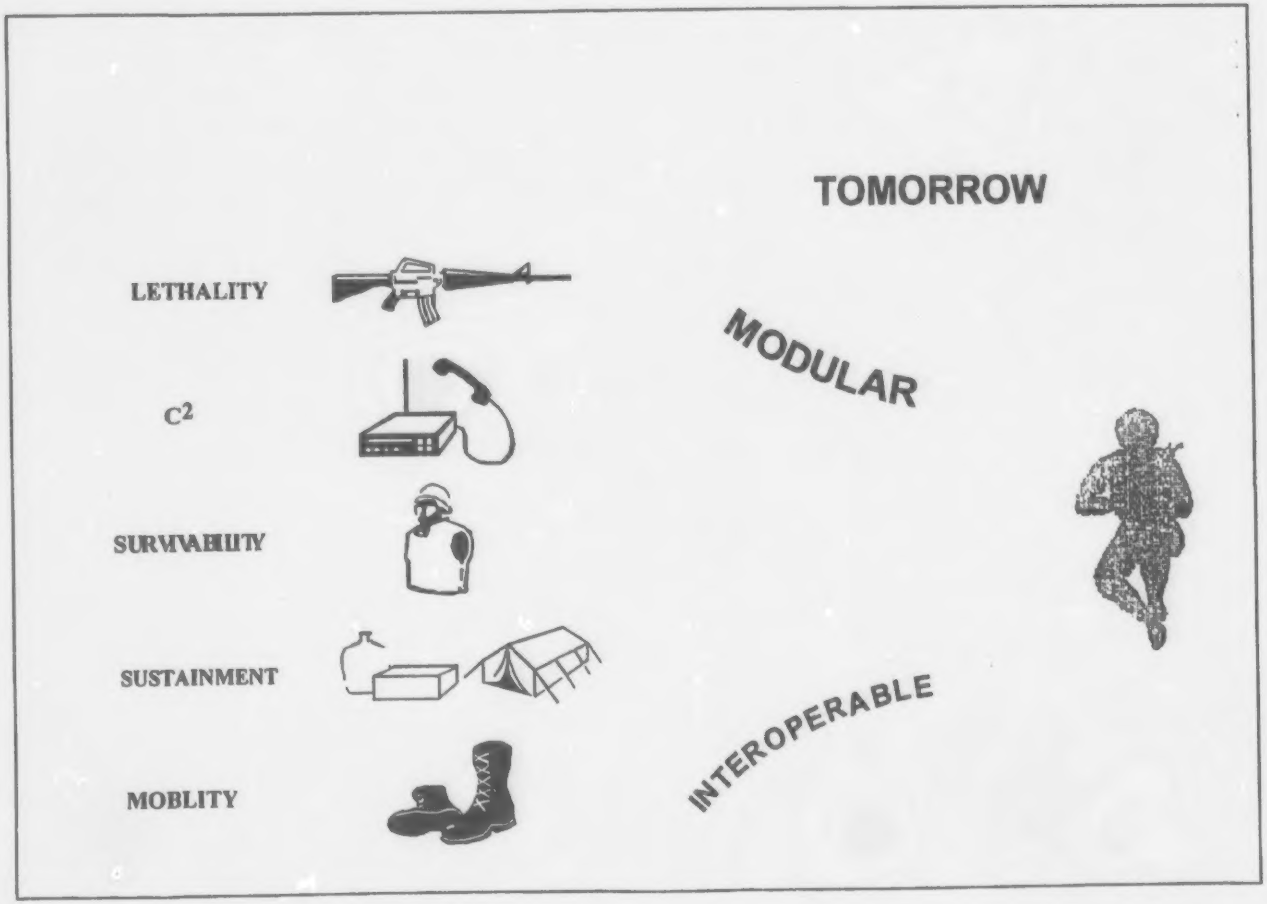
- *__Research, Development, and Acquisition (RDA):__* ***This domain includes: test and evaluation, training development, materiel development, and research and development technology base.***

- *__Training, Exercises, and Military Operations (TEMO):__* ***Includes most forms of training at all echelons from individual trainers through collective, combined arms, combined and joint exercises. Includes rehearsals for plans and operations and evaluations of completed missions.***

SPECTRUM OF ANALYTIC TOOLS


RESOLUTION
HIGH
LOW
ARMY MODEL IMPROVEMENT PROGRAM
INTERACTIVE
BATCH
SPE-CAD
CASRED
VLSTRACK
NUSSE
INTEGRATED UNIT SIMULATION SYSTEM (IUSS)
GWARS
JANUS
CASTFOREM
ModSAF
VIC
FORCEM
MEASUREMENT COMPONENT ITEM
SOLDIER SQUAD PLATOON
COMPANY BATTALION BRIGADE
BRIGADE DIVISION CORPS
CORPS ARMY THEATER
LOW
HIGH
COMBAT ECHELON

EVOLUTION OF THE SOLDIER SYSTEM & ITS MODELING



LETHALITY

C^2

SURVIVABILITY

SUSTAINMENT

MOBLITY

TOMORROW

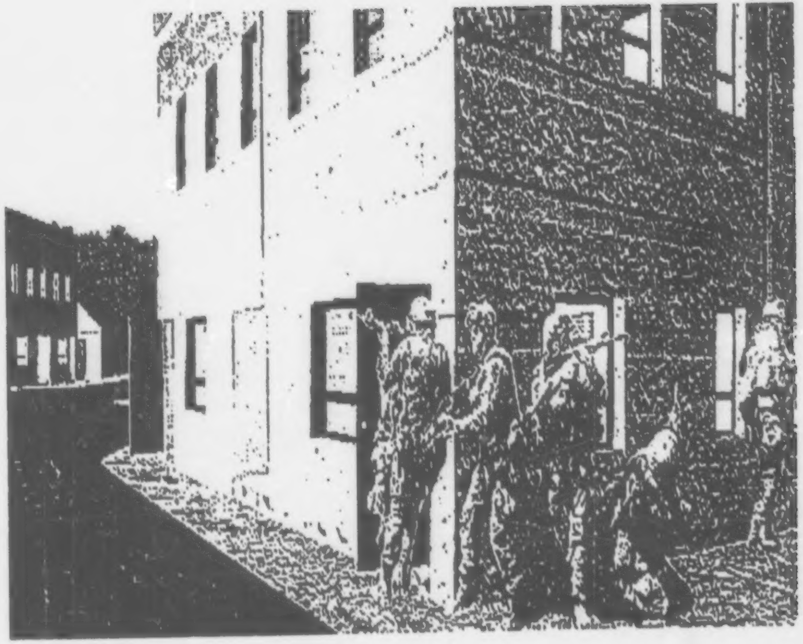
MODULAR

INTEROPERABLE

SOLDIER SYSTEM MODELING

OBJECTIVE

To support Soldier System decision makers by providing the capability to quantify the combat worth of projected materiel solutions through high fidelity simulation of the individual combatant



SOLDIER SYSTEM MODELING

APPROACH

- ***Promote rigorous analyses to quantify/evaluate alternative system concepts, equipment, and operational policy through:***
  - ***Development of a robust simulation environment to enhance analytical capabilities***
  - ***Formation of a mathematical basis to ensure accurate portrayal of the individual combatant and individual combatant behaviors***
  - ***Support of DoD High Level Architecture (HLA) and distributed simulation***

SOLDIER SYSTEM MODELING

CURRENT DIRECTIONS

- *Continue developing and maturing SSM methodologies to consider all aspects of individual combatant behavior and survivability including suppression, detection, and the effects of blast, ballistic fragments, small arms, and NBC weapons*

- *Maintain interoperability and compliance with latest DoD distributed and High Level Architecture (HLA) simulation standards and protocols*

- *Validate and verify the integrated implementation of underlying engineering and phenomenological models*

- *Co-develop and leverage a US DoD tri-service Operational Requirement-based Casualty Assessment (ORCA) model*

SOLDIER SYSTEM MODELING

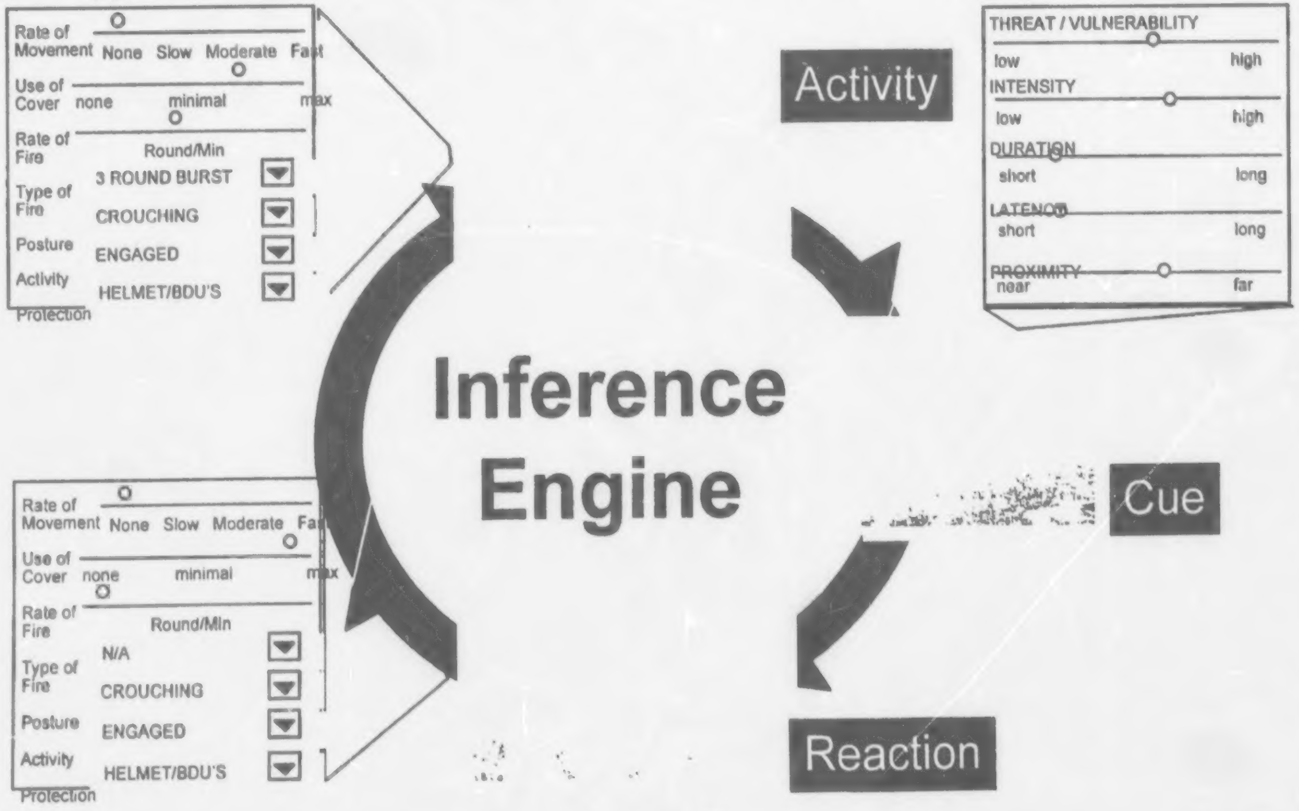
CHALLENGES

- ***Accurately portraying human behaviors and measuring performance***
- ***Combining conventional, non lethal and NBC weapons' effects***
- ***Integrating dissimilar methodologies into useful assessment tools***
- ***Ensuring adequate data archiving and retrieval capabilities and practices***
- ***Leveraging international Soldier System programs to:***
    - ***Influence experimental design, data collection, and algorithm development***
    - ***Share data and algorithms***
    - ***Codevelop algorithms and models***
    - ***Facilitate verification and validation of existing and evolving algorithms and models***
    - ***Explore coordinated distributed, soldier system focused, exercises***

SOLDIER SYSTEM MODELING

SPECIFIC EXAMPLE

- *Suppression: Human behavioral response critical to assessment of weapons effectiveness and determination of engagement outcomes*



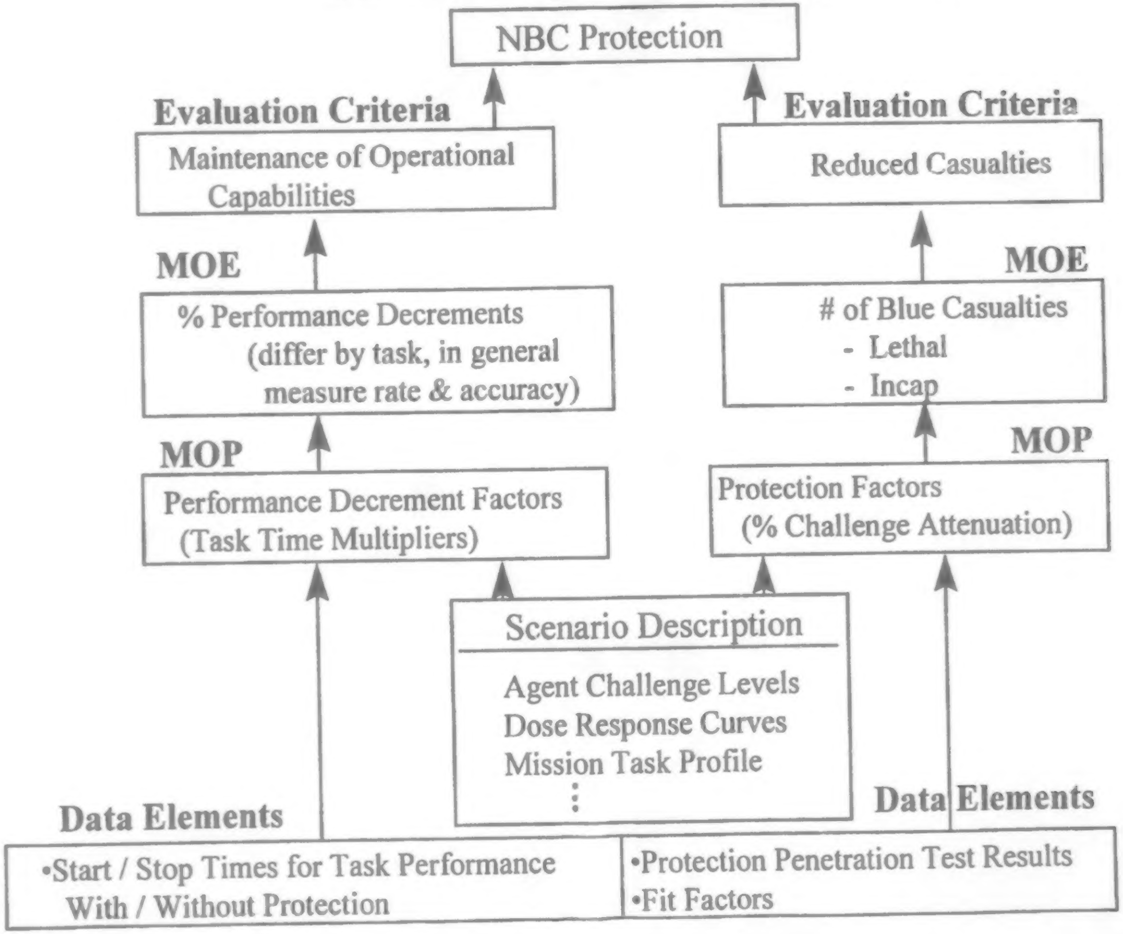
Rate of Movement: None Slow Moderate Fast
Use of Cover: none minimal max
Rate of Fire: Round/Min
Type of Fire: 3 ROUND BURST
Posture: CROUCHING
Activity: ENGAGED
Protection: HELMET/BDU'S

THREAT / VULNERABILITY: low – high
INTENSITY: low – high
DURATION: short – long
LATENCY: short – long
PROXIMITY: near – far

Rate of Movement: None Slow Moderate Fast
Use of Cover: none minimal max
Rate of Fire: Round/Min
Type of Fire: N/A
Posture: CROUCHING
Activity: ENGAGED
Protection: HELMET/BDU'S

COMBAT WORTH / MEASURE OF EFFECTIVENESS

Tactical - Operational Capability



NBC Protection

Evaluation Criteria

Maintenance of Operational Capabilities

MOE

% Performance Decrements (differ by task, in general measure rate & accuracy)

MOP

Performance Decrement Factors (Task Time Multipliers)

Evaluation Criteria

Reduced Casualties

MOE

# of Blue Casualties
- Lethal
- Incap

MOP

Protection Factors (% Challenge Attenuation)

Scenario Description

Agent Challenge Levels
Dose Response Curves
Mission Task Profile
⋮

Data Elements

- Start / Stop Times for Task Performance With / Without Protection

Data Elements

- Protection Penetration Test Results
- Fit Factors

1/24/97 Ottawa

SOLDIER SYSTEM MODELING

DEFINITIONS

- ***Measure of Performance (MOP): A defined metric of a component which contributes to basic system effectiveness as described by an MOE. MOPs relate to specific performance characteristics for which data can actually be collected.***

- ***Measure of Effectiveness (MOE): A quantitative expression which compares the effectiveness of alternatives in meeting an operational objective or need.***

- ***Measure of Combat Worth: Factors affordability into a measure of effectiveness.***

SOLDIER SYSTEM MODELING

WHAT IS REQUIRED

- *High resolution, comprehensive data bases of:*
  - *–cognitive, behavioral and physiological effects on performance,*
  - *–physical measurements of battlefield environments: terrain,cultural features, dynamic phenomenological effects,and*
  - *–systems' characteristics*

to accurately portray the behaviors and capabilities of individual combatants and small units

SOLDIER SYSTEM MODELING

WHAT IS REQUIRED - Continued

- ***Vulnerability methods considering the full range of battlefield insults, accepted dose response data and verified inferential methods to combine conventional, non lethal and NBC weapons' effects to estimate individual combatant survivability and performance attributable to alternative protective system concepts***

SOLDIER SYSTEM MODELING

RECOMMENDATIONS

- ***Under the auspices of the QWGAOR Special Working Group on Soldier as a Combat System develop a work plan to specifically:***
  - ***-Define standard MOPS/MOEs for integrating data and engineering metrics into useful assessment tools***
  - ***-Identify and pursue collaborative experimental design, data collection, as well as algorithm/model development efforts***
  - ***-Support joint distributed simulation efforts as another means of coordinated data collection***

SOLDIER SYSTEM MODELING

SUMMARY

- *We have presented our view of the way M&S supports the Soldier System and Soldier System decision makers*
- *We have provided an overview of our approach and current directions towards enhancing them*
- *We have identified areas for mutual interaction and benefit*

Dismounted Infantry Modeling: IUSS, CAEN and the Future

Presented at the Soldier
Modeling Workshop,
National Defence Headquarters,
Ottawa, Canada
27-31 January 97

by Matthew A. Rosenblatt
U. S. Army Materiel
Systems Analysis Activity,
Aberdeen Proving Ground,
Maryland

What We Are Bringing to This Workshop

- What the U.S. has done in Dismounted Infantry (DMI) modeling since the QWG AOR meeting of July 95
- What the U.S. Army wants to analyze using DMI models
  - Systems and Scenarios
  - Present, Near-term, and Long-term
- Measures of Effectiveness (MOEs) and Measures of Performance (MOPs)
  - Not all directly quantifiable in terms of Probability of Hit (P_h) and Probability of Kill (P_k)
- The Integrated Unit Soldier System (IUSS), and knowledge of what it can do

What We Hope to Learn at This Workshop

- What have the other participant countries done in DMI modeling since the QWG AOR meeting of July 95?
- Which existing models can handle each MOE and MOP?
  - As currently configured and operational
  - With changes currently under way
- What has to be done to handle MOEs not included above?
  - Time and cost estimates (GANTT charts)
  - Change existing models (*e.g.*, make CAEN "U.S.-friendly")?
  - Develop a new model?

Dismounted Infantry Requirements

Improve the combat soldier's capabilities in these areas:

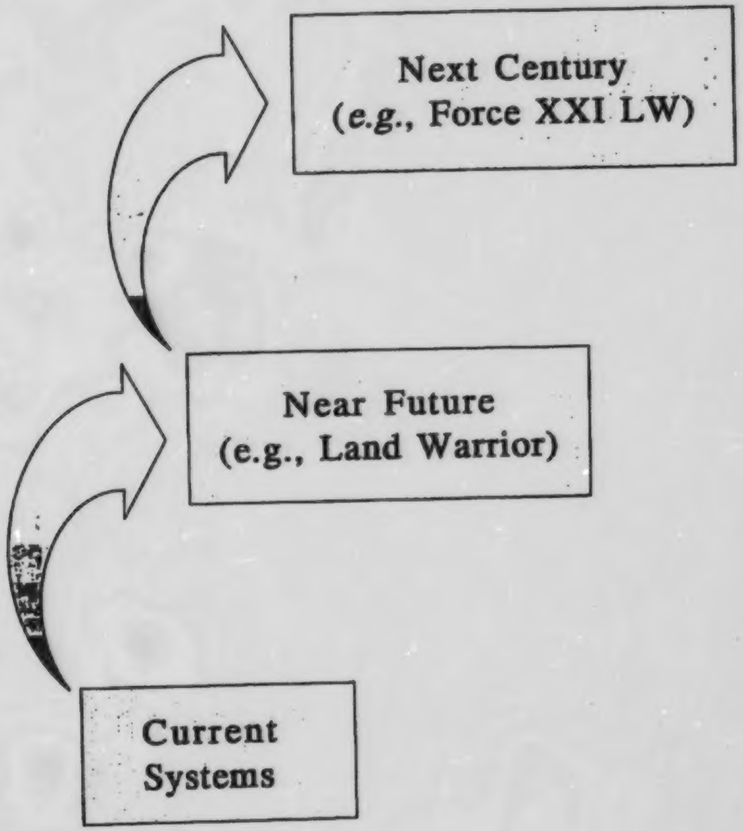
Lethality - improved target acquisition and servicing in all battlefield environments, day and night

Command and Control - improved communication, combat command decisions and situational awareness and understanding.

Survivability - improve survivability and reduce detectability across the spectrum of enemy weapon systems.

Sustainability - improve the soldier's ability to sustain himself and his equipment.

Mobility - improve dismounted mobility, trafficability and mission routing.



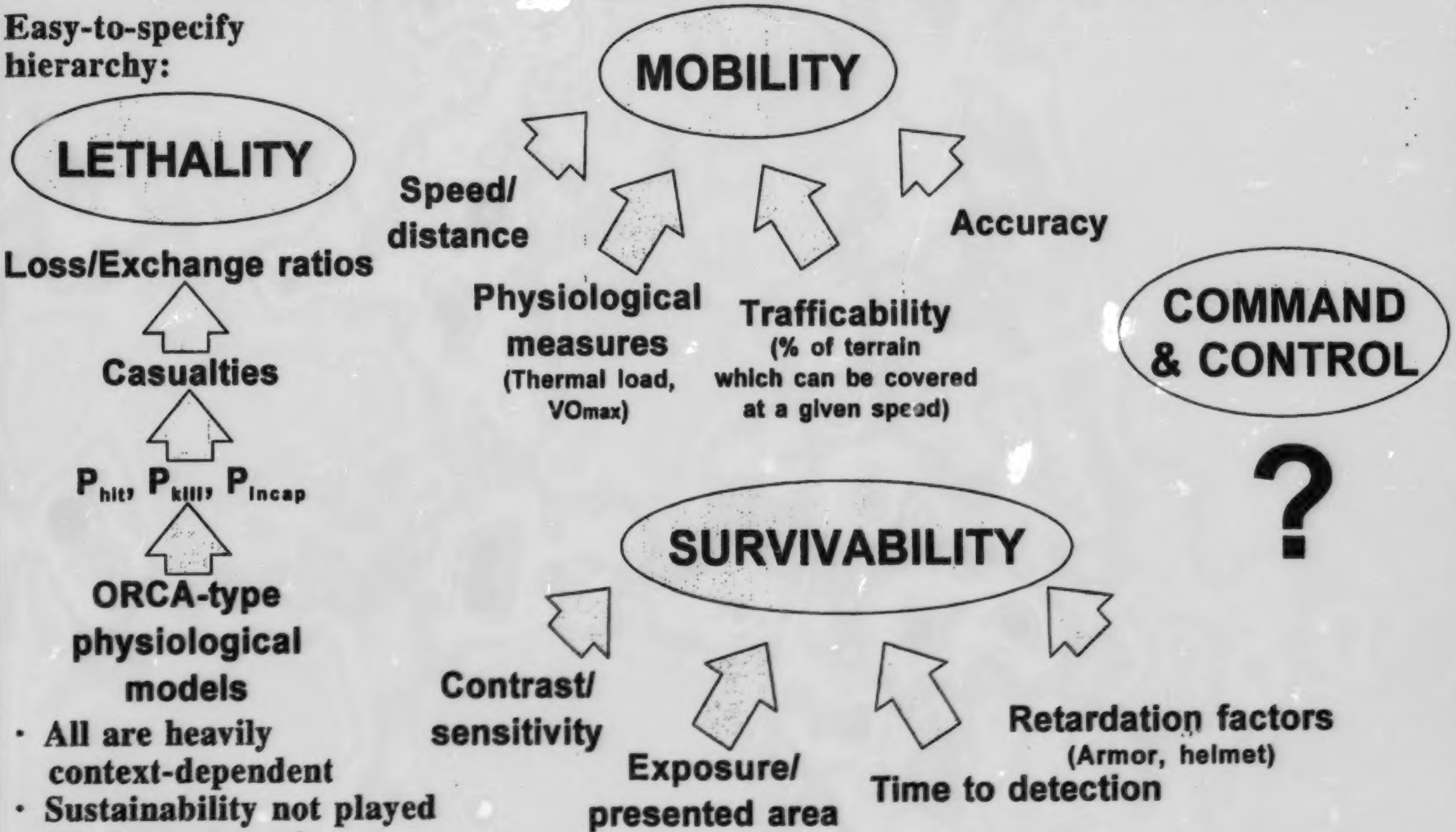
Next Century
(*e.g.*, Force XXI LW)

Near Future
(e.g., Land Warrior)

Current
Systems

Measures of Effectiveness That Soldier System Models Provide

OVERALL MOEs: Mission Accomplishment, Casualties



Easy-to-specify hierarchy:

LETHALITY

Loss/Exchange ratios

Casualties

P_{hit}, P_{kill}, P_{incap}

ORCA-type physiological models

MOBILITY

Speed/ distance

Physiological measures (Thermal load, VOmax)

Trafficability (% of terrain which can be covered at a given speed)

Accuracy

COMMAND & CONTROL

?

SURVIVABILITY

Contrast/ sensitivity

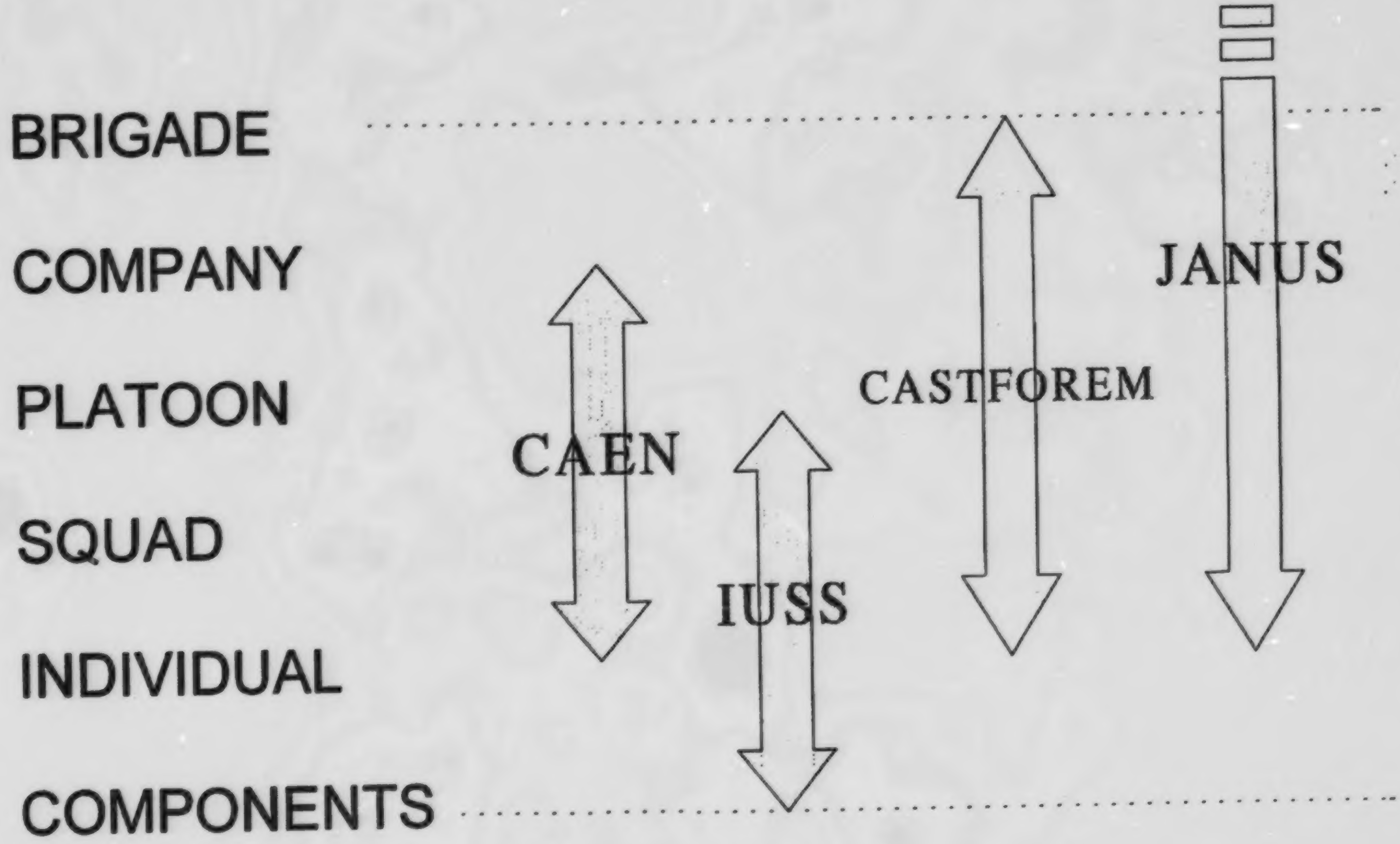
Exposure/ presented area

Time to detection

Retardation factors (Armor, helmet)

- All are heavily context-dependent
- Sustainability not played in short scenarios

Echelons of Interest



BRIGADE

COMPANY

PLATOON

SQUAD

INDIVIDUAL

COMPONENTS

JANUS
CASTFOREM
CAEN
IUSS

Features

Research, Development
and Acquisition world

IUSS Emphasizes

- Engineering/ 1st-principle models
- Physiology
- Equipment
- Protection
- Vulnerability

Both Models Play

- Movement
- Soldier weapons
- Artillery
- Ammunition
- Sensors/FOV
- Terrain
- Weather
- Barrier warfare
- Gas warfare
- Suppression
- Injury

Training Exercise and
Military Operations world

CAEN Emphasizes

- Commander's tactical flexibility
- MOUT
- Mount/Dismount
- 3-D playback

Modeling Issues

ISSUE			GOAL
Terrain/ Mobility (includes obstacles)	IUSS:	CTDB Version 5 MCC Stochastic Shield	Comparability of results at a fine level of resolution
	CAEN:	JANUS-compatible Heightened-resolution features Automatic formations: cordons, wedges Avoidance of buildings	
MOUT	IUSS:	Outdoors only	Movement rates Behavior in bldgs Use of structures Impact of structure failure on the soldier
	CAEN:	Inside & outside buildings	

Modeling Issues
(cont'd)

ISSUE			GOAL
Sensors	IUSS:	MRT/MRC curves	Models starting at first principles from the human; Granular individual-specific detection, identification & engagement
	CAEN:	ORACLE detection model	
Suppression	IUSS & CAEN:	Threat/proximity duration/suppression	Better representation of less-than-lethal events

Modeling Issues
(cont'd)

ISSUE			GOAL
Weapons of mass destruction	IUSS:	Agent attenuation, casualties (not transport)	Capture effects of MOPP
	CAEN:	Riot agents only	
Casualty modeling	IUSS:	Detailed physiological modeling of effects	Better representation of less-than-lethal events
	CAEN:	Hit-kill or Hooks Injured may be helped from the scene	

Modeling Issues (concl.)

ISSUE		GOAL
Human factors	**IUSS:** Physiological model **CAEN:** Lack of mobility	Model the effects of loading soldier with new equipment
Executability	**IUSS:** PC, under Windows **CAEN:** DEC Alpha, under VMS	Inexpensive, commonly available, off-the-shelf hardware and software

IUSS/CAEN -
Summary Assessment

- IUSS and CAEN each has unique purpose and application.

- IUSS will be primary tool for item level performance of Force XXI LW.

- Need capability beyond IUSS - battalion/brigade level.

- CAEN has important modeling capabilities not available in IUSS:
  - company level
  - MOUT
  - mounted warfare

- CAEN use not practical because of peculiar HW/SW.

Methodology and Data Needed

- IUSS and CAEN started from different application domains but are converging to complementary methodologies.
- We need to coordinate methodology development to optimize dismounted infantry models.
- Data Dependencies -- a requirement for VV&A'd data -- are a critical accompaniment to methodology development.

U.S. Army Strategy - Soldier System Modeling

Near Term:

- Near term requirement is AoA for Land Warrior.
- Use dismounted CASTFOREM with IUSS input.
- Initiate QWG efforts to:
  - leverage data collection and experimental design to support IUSS/CAEN
  - insure comparable results for modeling overlap in IUSS and CAEN

Longer Term:

- Need to integrate IUSS in battalion/brigade level modeling.

  Options:
  - Adapt CAEN for user friendly HW/SW; develop interface with IUSS
  - Improvements to Dismounted CASTFOREM
  - New model development

Soldier Modeling Workshop

Land Warrior
Force XXI Land Warrior

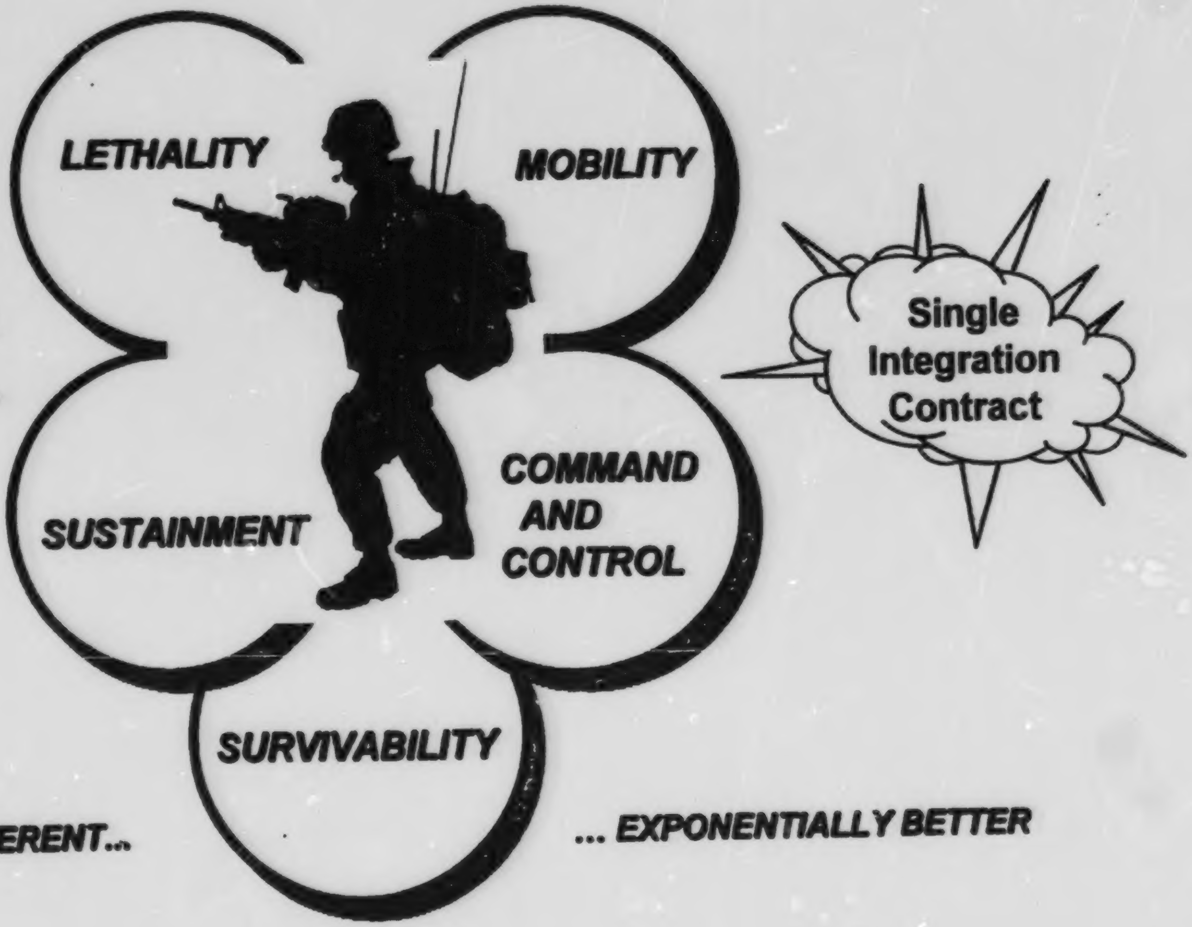
Soldier Station

Robert O'Brien
Soldier Systems Command
Natick, MA

Phone: 508/233-4924
Email: robrien@natick-emh2.army.mil

A SYSTEM OF SYSTEMS

**" EVERYTHING WORN,
CONSUMED OR
CARRIED FOR INDIVIDUAL
USE IN A
TACTICAL ENVIRONMENT "**



LETHALITY

MOBILITY

SUSTAINMENT

**COMMAND
AND
CONTROL**

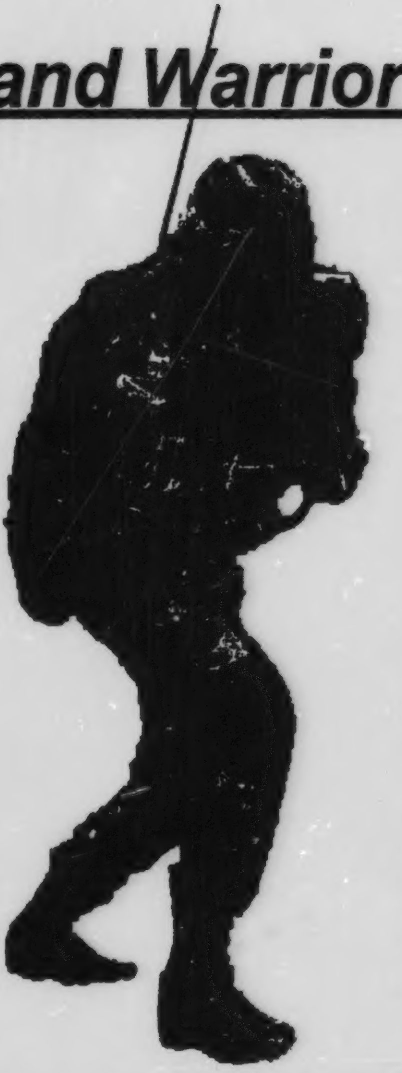
SURVIVABILITY

**Single
Integration
Contract**

FUNDAMENTALLY DIFFERENT...

... EXPONENTIALLY BETTER

The Land Warrior System



Computer/Radio Subsystem

Computer
Soldier Radio w/(†)Packet Relay
Squad Radio
GPS w/(†)Integrated Navigation
Handheld Flat Panel Display
Video Capture
Compatible With Combat ID Component
† Color Handheld Flat Panel Display
† System Voice Control
† Interface to Instride Mine Avoidance

Protective Clothing and Individual Equipment Subsystem

Advanced Load Carrying Capability
Modular Body Armor
** Chem/Bio Garment/Glove/Boot
* Other Existing CIE
† Combat ID
† Personal Status Monitor
† Lightweight Chemical Agent Detector

Software Subsystem

Software
* GFE Software

Integrated Helmet Assembly Subsystem (IHAS)

Lightweight Helmet With Suspension
Helmet-Mounted Display (Improved Display)
Image Intensifier (I^2) With Integrated Flat Panel Display
Laser Detectors
** XM45 Chem/Bio Mask
* Ballistic/Laser Eye Protection
† Head Orientation Sensor
† Integrated, Improved IHAS w/Indirect Optic to HMD

Weapon Subsystem

Laser Rangefinder
Digital Compass
Wiring Harness/(†)Wireless Weapon Interface
Video Camera
** Modular Weapon System
** Thermal Weapon Sight (TWS)
** Close Combat Optic
* AN-PAQ4C - IR Laser Aiming Light
* Other Existing Weapons & Accessories
† Integrated Sight (Replaces LRF/DC, TWS & Aiming Light)
† Objective Individual Combat Weapon

BLACK = LW Development and Integrated Into LW by Contractor
RED** = GFE to K (Still Being Developed); Integrated Into LW System
GREEN* = GFE to K (Already Type Classified); Integrated Into LW System
BLUE† = Candidates for Tech Insertion

FXXI LW TECHNOLOGY INSERTION CANDIDATES

High Priority:

Combat ID
Wireless Weapon Interface
Integrated Sight
Integrated Navigation (Self-Contained Merged With GPS)
Enhanced Soldier Radio (Packet Radio Relay for Longer Range)
System Voice Control
Helmet Mounted Display Upgrades

High operational payoff
Acceptable schedule

Medium Priority:

Hand Held Color Display
Head Orientation Sensor

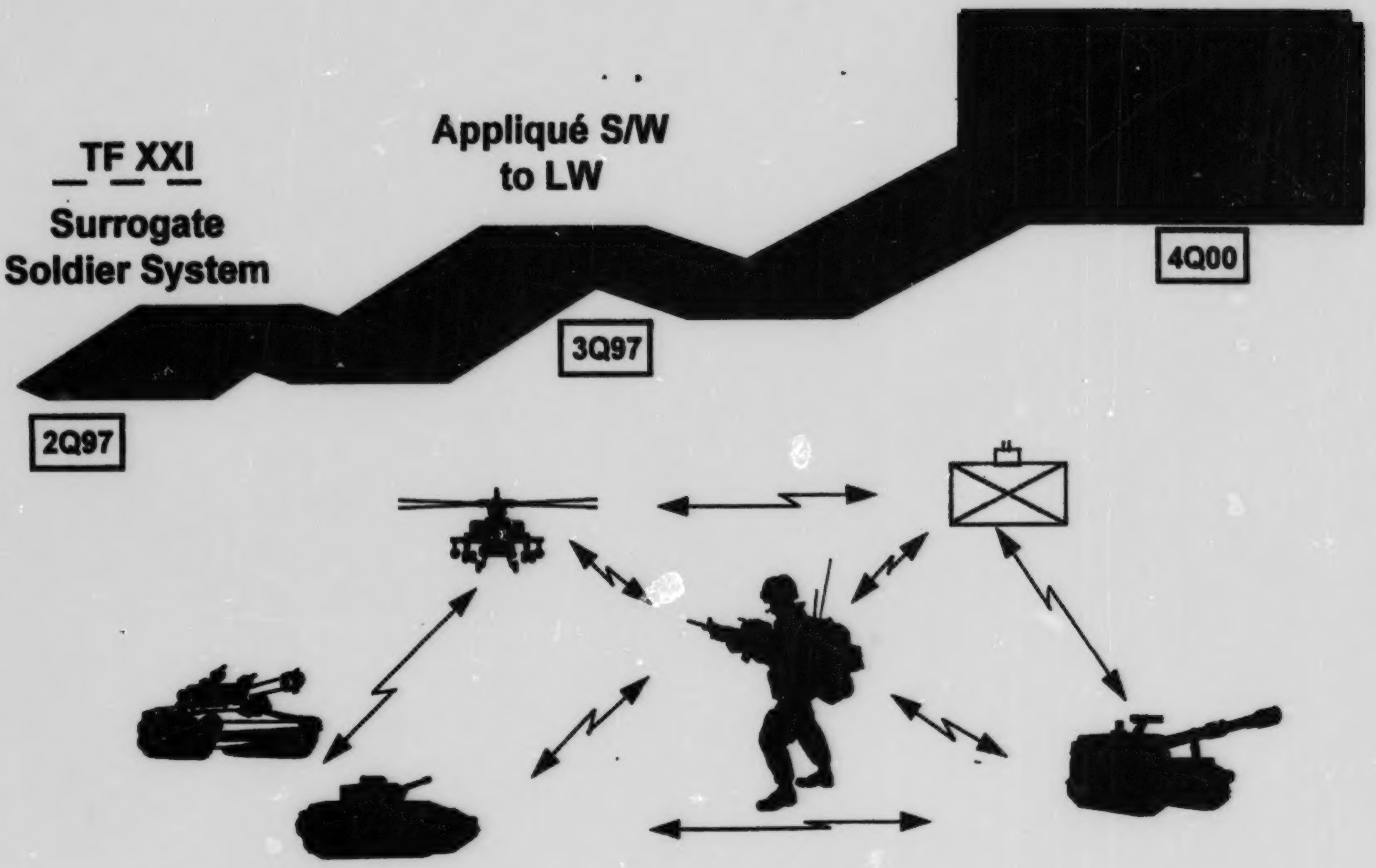
Operational payoff
Acceptable schedule
Weight risk on helmet

Low Priority:

Personnel Status Monitor
Instride Manportable Mine Avoidance Interface
Lightweight Chemical Agent Detector Interface

Operational payoff
Less mature technology
Interfaces

Land Warrior In the Digitized Net



TF XXI
Surrogate
Soldier System

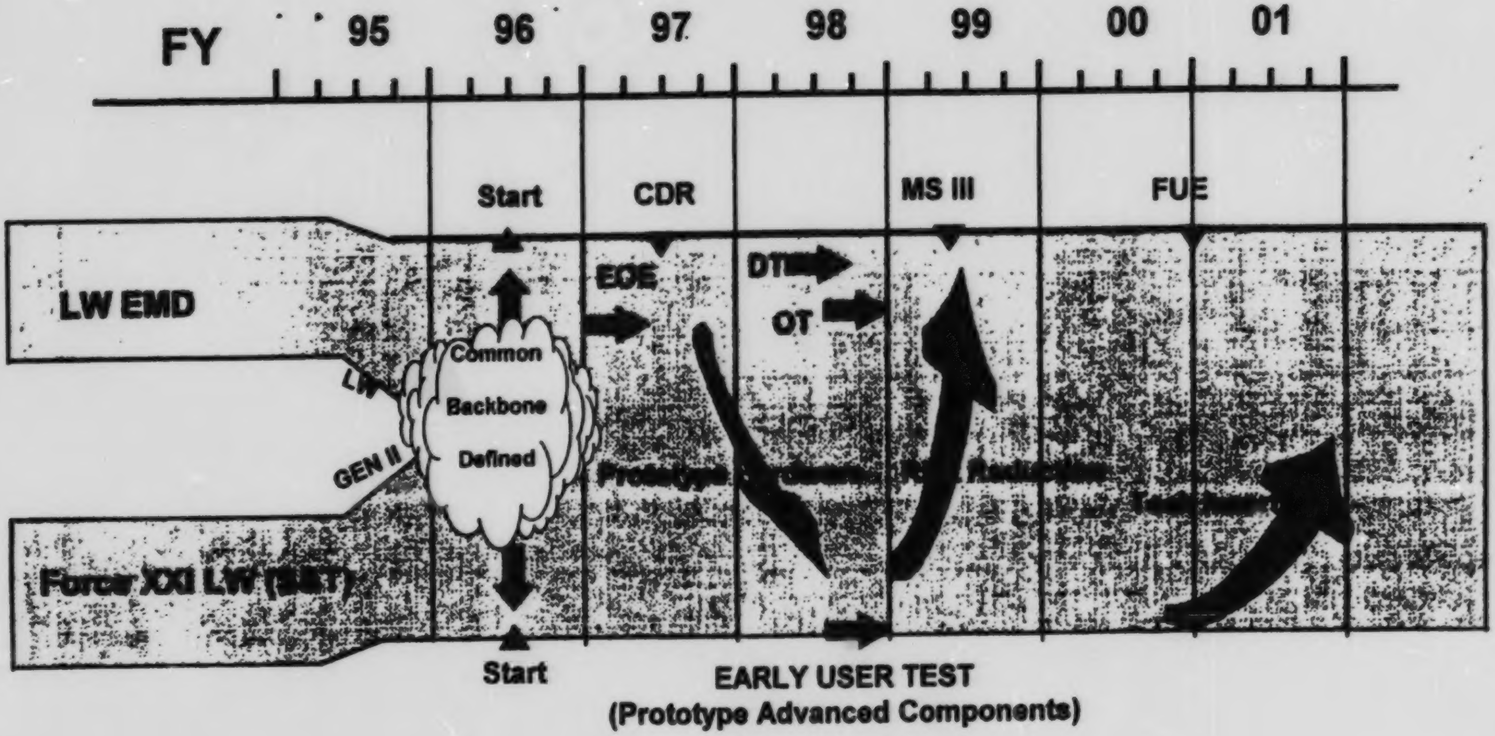
Appliqué S/W
to LW

2Q97

3Q97

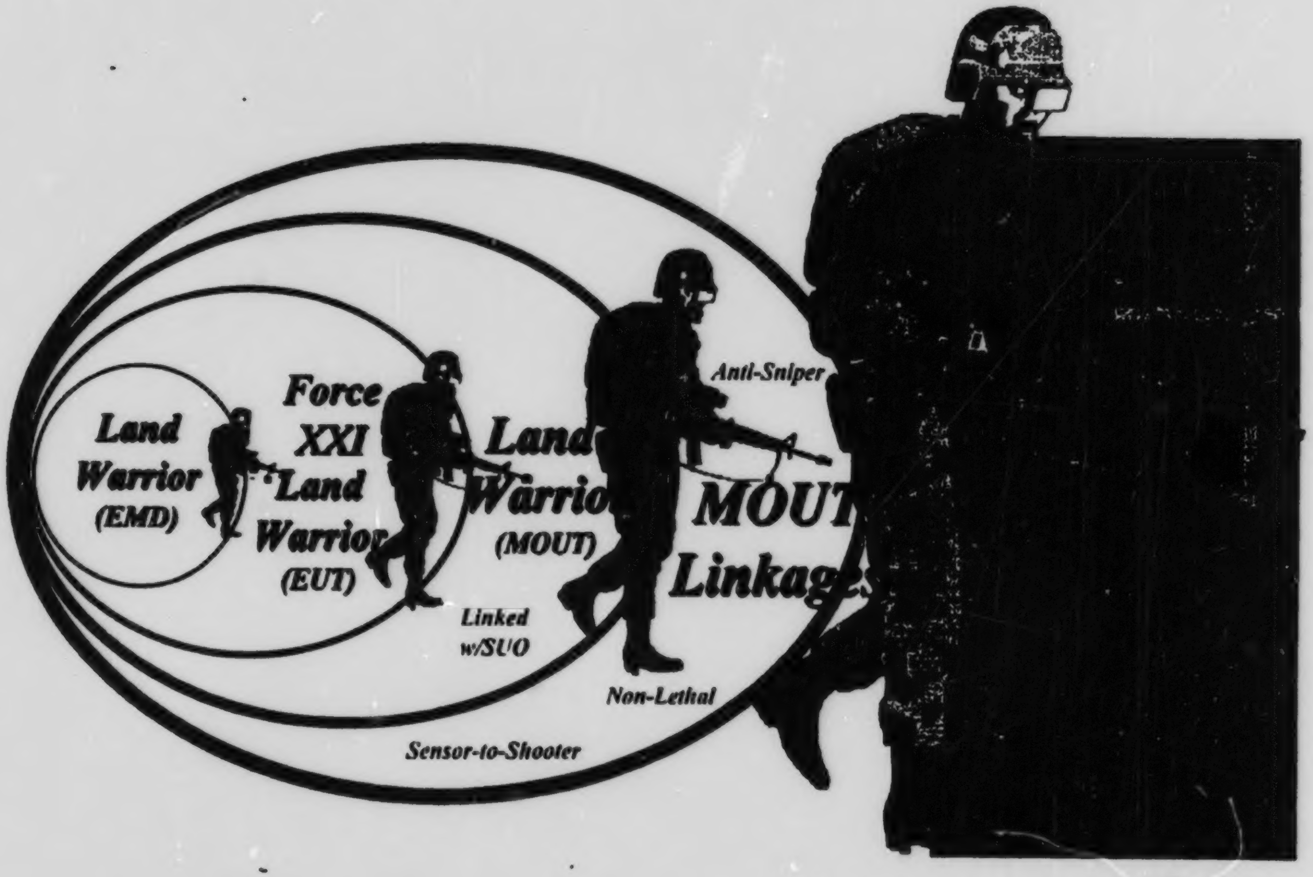
4Q00

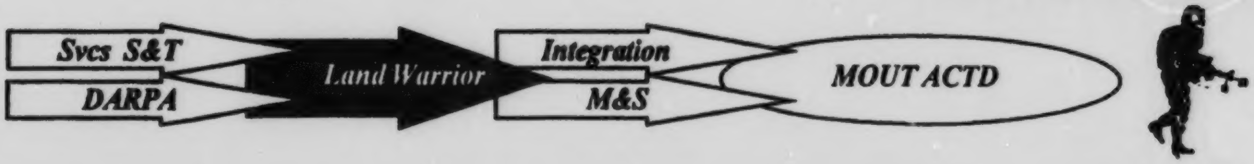
Land Warrior Schedule



EARLY USER TEST
(Prototype Advanced Components)

Land Warrior Progression


Land Warrior (EMD)
Force XXI Land Warrior (EUT)
Land Warrior (MOUT)
MOUT Linkages
Anti-Sniper
Linked w/SUO
Non-Lethal
Sensor-to-Shooter


Svcs S&T
DARPA
Land Warrior
Integration
M&S
MOUT ACTD

Measures of Effectiveness
Measures of Performance

Under Development

MOE

MOP

System Components

Data

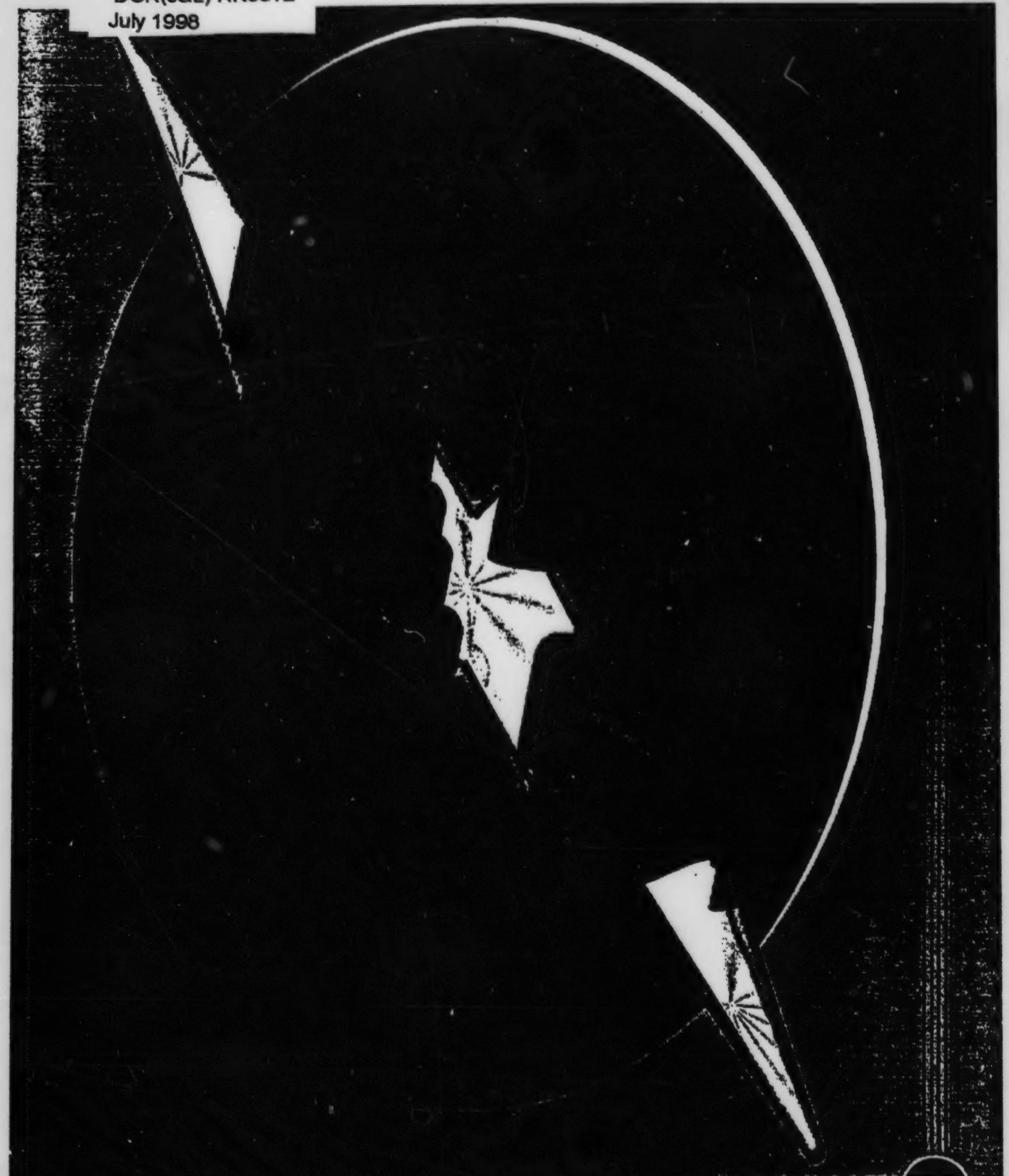
Data Sources

- ***Field, Simulation/Analysis, Historical***

Data Collection Requirements

- ***Instrumentation, Data Capture, Post Processing***

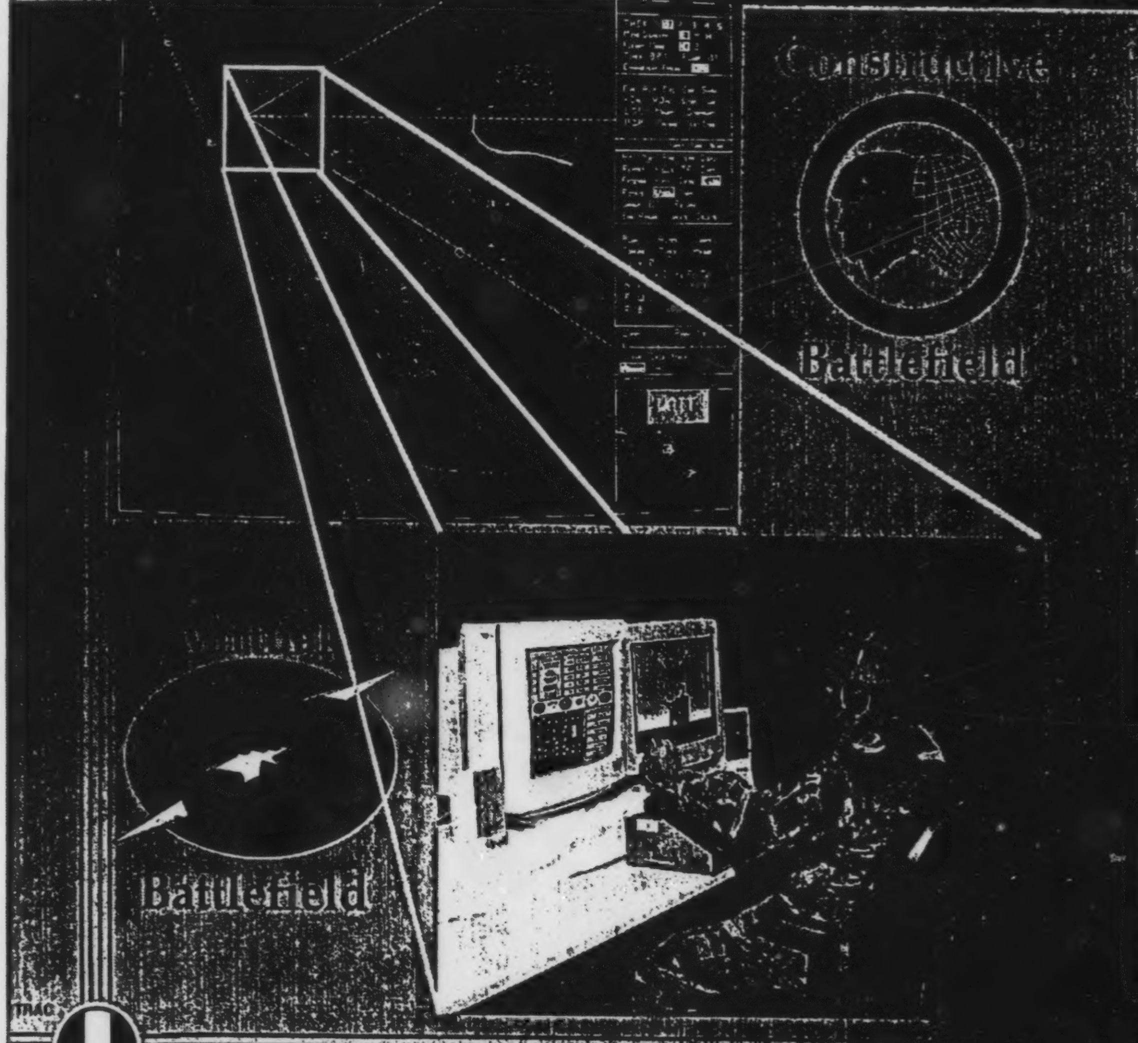
ANNEX Q
DOR(J&L) RN9812
July 1998



Purpose

- ☆Develop an analytical tool that allows TRAC to address these dismounted infantry issues:
  - ✓ Situational Awareness
  - ✓ Command and Control
  - ✓ Tactics, Techniques, and Procedures

Evolution


Constructive
Battlefield
Battlefield

Phase I

- Analytical tool designed to meet COEA requirements
- Emphasized software architecture

Phase II

- Combat ID
- Task Force XXI
- Land Warrior

Phase III

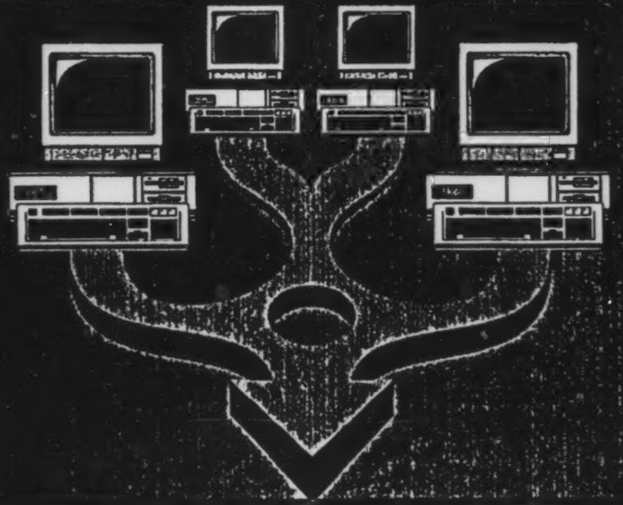
- MOUT

TRAC WSMR *Excellence In Analysis*

Soldier Station:

The Bridge Between Constructive And Virtual Infantry

Constructive

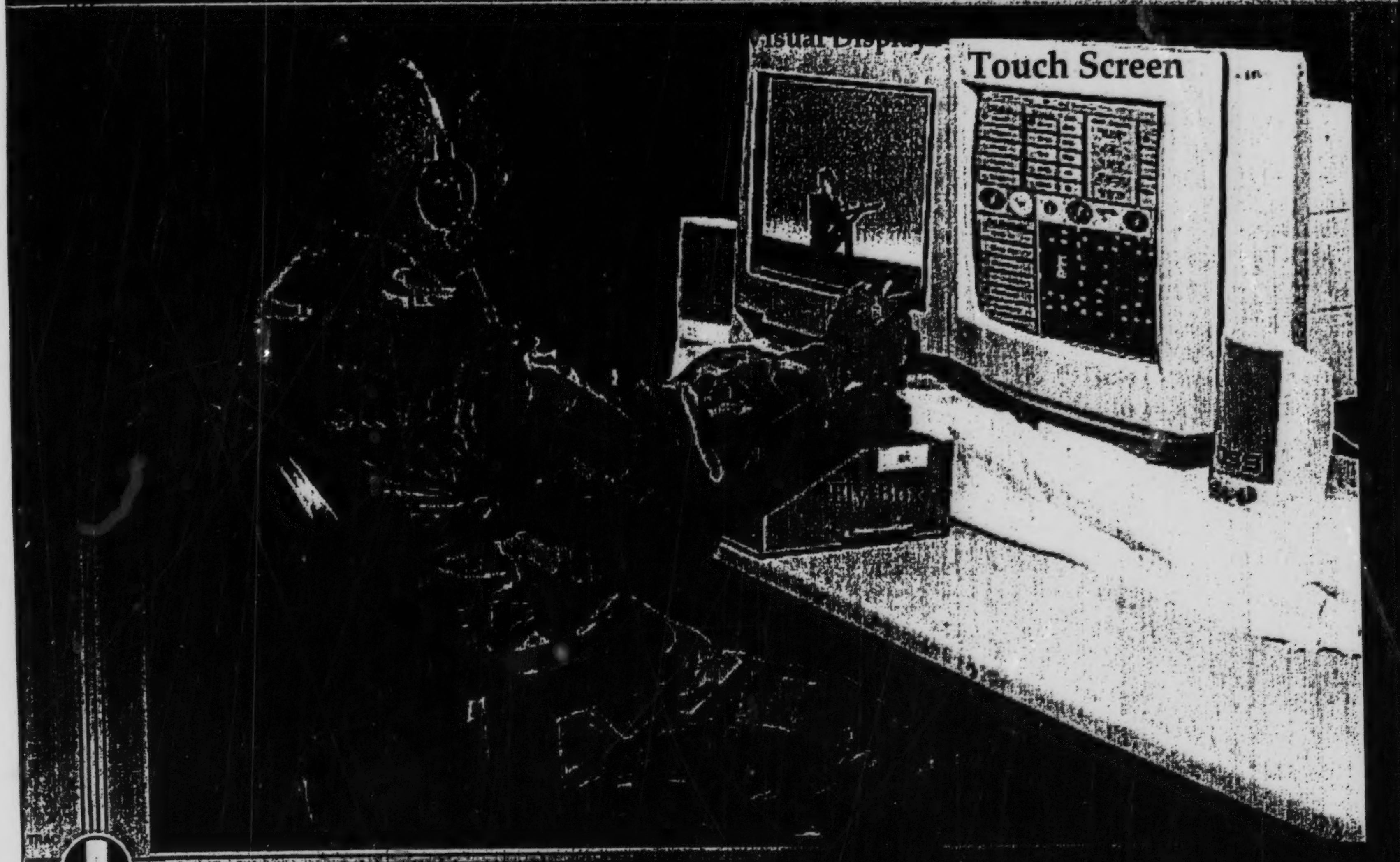


- ✓ Semi-Automated Forces Dismounted Infantry (SAFDI)
- ✓ Janus
- ✓ CASTFOREM
- ✓ IUSS

Virtual

DIS Compatible

Soldier Station


Visual Display
Touch Screen
Fly Box

Excellence In Analysis

Tactical Player

Features

- ✓Human Component
- ✓Communications
- ✓Situational Awareness
- ✓Command and Control
- ✓Tactics, techniques, and Procedures

TRAC

Excellence In Analysis

Visual Display

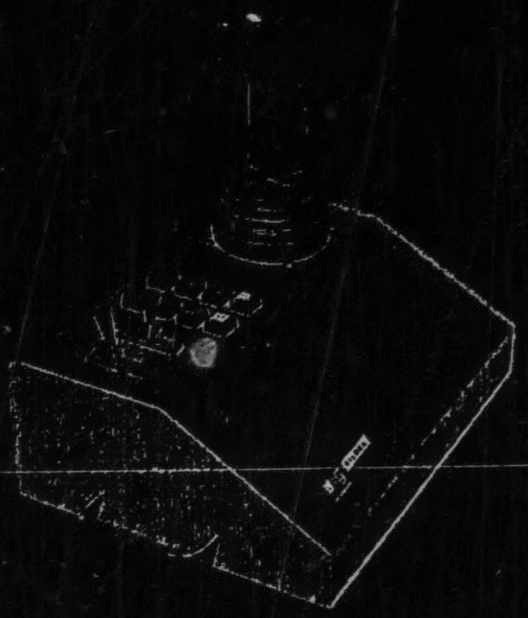
Field Of View

- ➥Three-dimensional Perspective of the Battlefield

Based On

- ★Soldier's Sensor
  - ✓Eyes
  - ✓Binoculars
- ★Weapon Selection
- ★Soldier's Posture

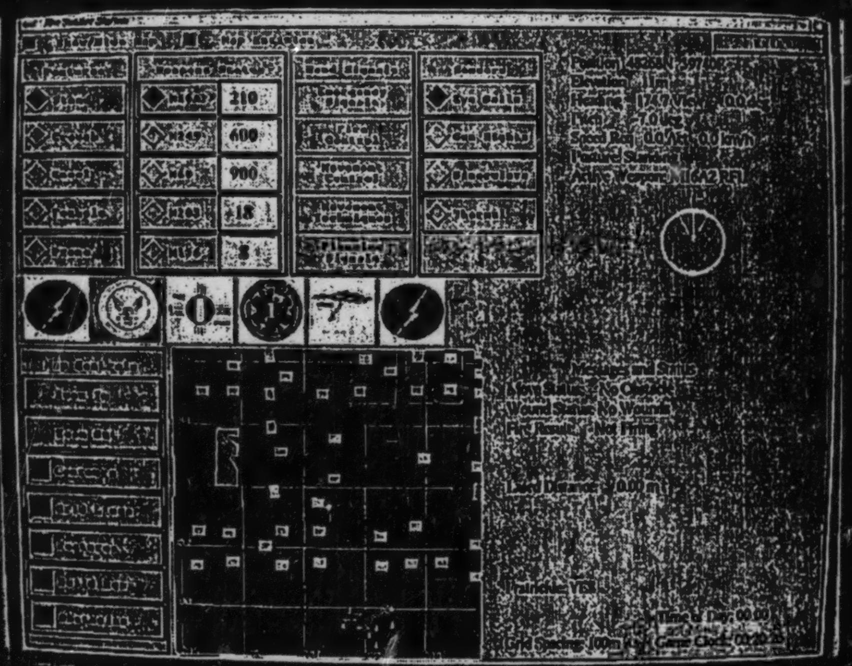
Fly Box



Features

- ✓Levers
  - ➢Movement and Speed
- ✓Switches
  - ➢Standing
  - ➢Crouching
  - ➢Kneeling
  - ➢Realign head
  - ➢Prone
  - ➢Foxhole
  - ➢Deploy weapon
  - ➢Laser ranging
- ✓Three-axis Joystick
  - ➢Movement direction
  - ➢View direction
  - ➢Weapon trigger
  - ➢Head and weapon pitch

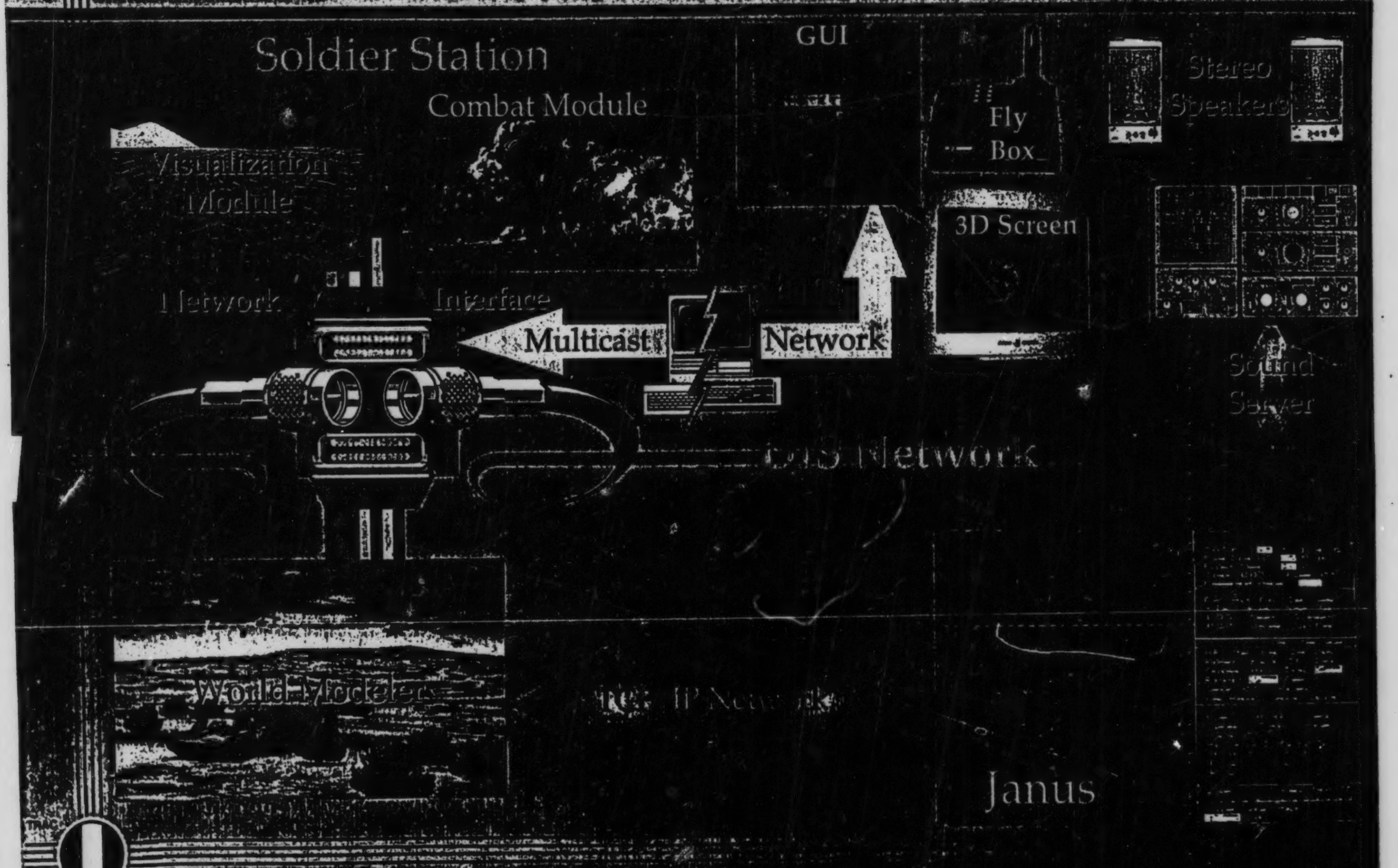
Touch Screen



Features

- ✓Weapons Selection
  - ➢Rounds Remaining
- ✓Sensor Selection
  - ➢Eyesight
  - ➢Binoculars
  - ➢Night Vision System
- ✓Hand and Arm Signals
- ✓Electronic Map Display
- ✓Electronic Compass
- ✓Soldier Status and Location
- ✓Text Feedback Information
- ✓Different Era Soldiers

System Architecture


Soldier Station
Combat Module
Visualization Module
GUI
Fly Box
Stereo Speakers
3D Screen
Network Interface
Multicast
Network
Sound Server
DIS Network
World Modeler
TCP/IP Network
Janus

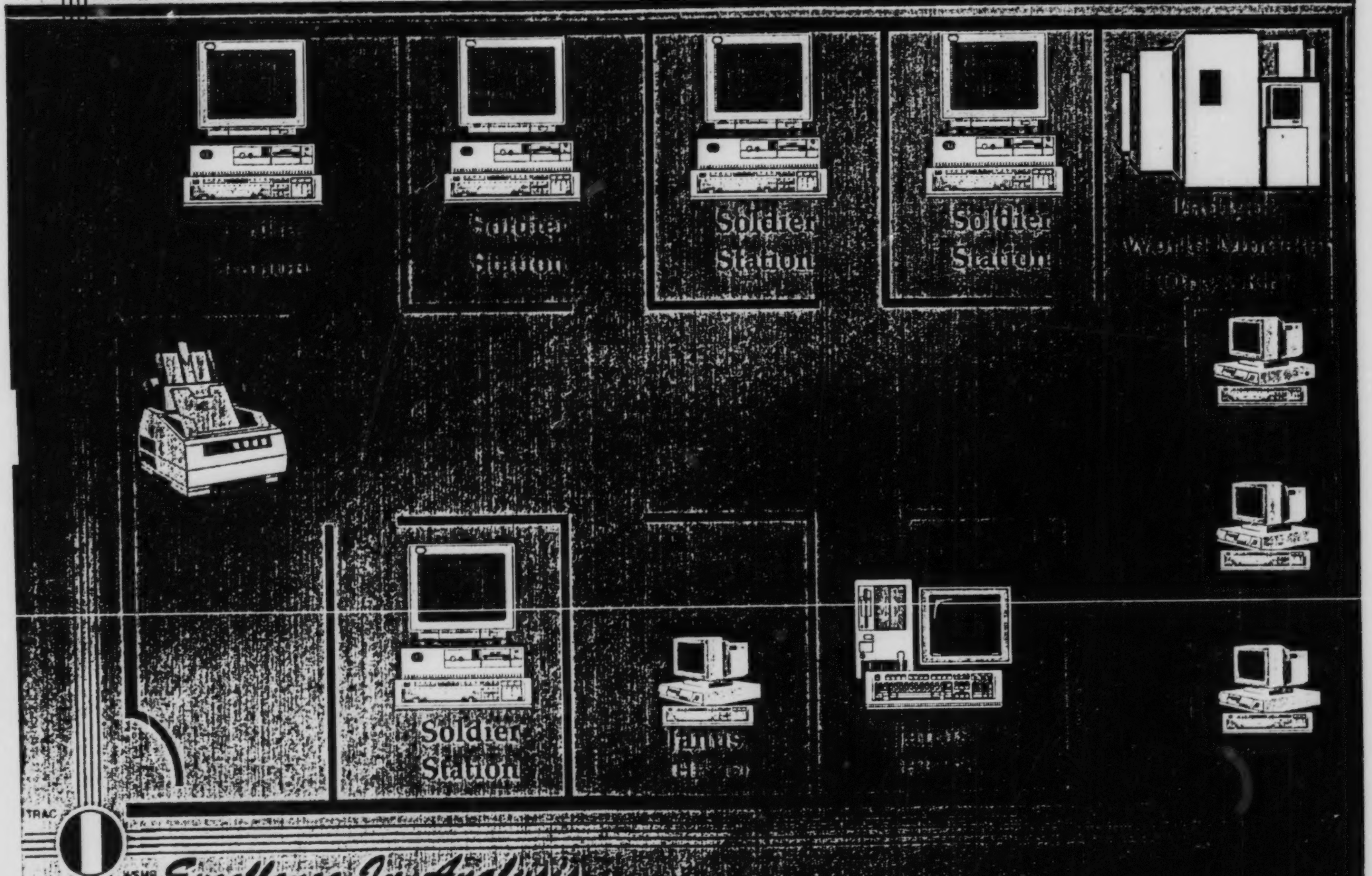
Excellence In Analysis

Land Warrior Capabilities

- ✓ Smoke Display and Effects
- ✓ Level of Detections
- ✓ Voice Control of Common Functions
- ✓ Wound Effects
- ✓ Multiple Sides/Uniforms
- ✓ Improved MOBA Representation
- ✓ Thermal Weapons Sight
- ✓ Objective Individual Combat Weapon
- ✓ Combat Identification System
- ✓ Laser Range Finder
- ✓ Global Positioning System
- ☛ Integrate Soldier Radio/Computer
- ☛ Video Capture/Transfer
- ☛ Integrate EOE Scenario

TRAC WSMR *Excellence In Analysis*

Soldier Station Suite


Soldier
Station
Soldier
Station
Soldier
Station
Soldier
Station
Soldier
Station
Janus

TRAC WSMR *Excellence In Analysis*

Force XXI Land Warrior
Measures of Performance
DRAFT, January 1997

CAPABILITY AREA	MAJOR ISSUES	MOEs/MOPs	DATA REQUIREMENTS
LETHALITY	1. Capability To Place Accurate Fire On The Enemy Without Exposing Self To Fire	MOE	DATA
		• Total BLUE Dismounted Infantry casualties	• Total casualties to BLUE Dismounted Infantry
		• % of Total Casualties from BLUE Dismounted Infantry (small arms) with / without unexposed fire capabilities	• Casualties to BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities
		• Total OPFOR casualties	• Total OPFOR casualties
		• % of total OPFOR casualties from BLUE Dismounted Infantry (small arms) with / without unexposed fire capabilities	OPFOR casualties from BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities, indirect fire, other causes
		• avg. rounds/OPFOR casualty from BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities	• rounds fired from small arms fire from exposed/unexposed positions
		MOP	
		• % of exposure when firing from covered position	• % of exposure when firing from covered position
		• P(h) from BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities	• accuracy of BLUE Dismounted Infantry(small arms) with and without unexposed fire capabilities
		• avg. engagement time for BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities	• engagement times of BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities
		• avg. range of OPFOR casualties by BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities	• range to each OPFOR casualty from BLUE Dismounted Infantry (small arms) with and without unexposed fire capabilities

Force XXI Land Warrior

Measures of Performance

DRAFT, January 1997

LETHALITY	**3. Dismounted Infantry (DI) Ability To Incapacitate Tanks / Light Vehicles**	**MOE** • # of OPFOR tanks and light vehicle casualties from DI • DI anti-tank rounds / OPFOR tank and vehicle casualty **MOP** • P(h) from BLUE Dismounted Infantry (small arms) with anti- tank / light vehicle capabilities • avg. range of tank and light vehicle casualties	**DATA** • total tank and light vehicle casualties • total tank and light vehicle casualties from DI • # DI anti-tank rounds fired • accuracy of BLUE Dismounted Infantry (small arms) with anti- tank / light vehicle capabilities • range of tank casualties
LETHALITY	**8. Given A Shot, Probability Of An Enemy Soldier Casualty (Day/Night)**	**MOE** • Total BLUE Dismounted Infantry casualties • % of Total BLUE Dismounted Infantry casualties from BLUE Dismounted Infantry (small arms) • Total OPFOR casualties • % of total OPFOR casualties from BLUE Dismounted Infantry (small arms) • avg. rounds/OPFOR casualty from BLUE Dismounted Infantry (small arms) **MOP** • P(h) from BLUE Dismounted Infantry (small arms)	**DATA** • Total casualties to BLUE Dismounted Infantry • Casualties to BLUE Dismounted Infantry (small arms) • Total OPFOR casualties • OPFOR casualties from BLUE Dismounted Infantry (small arms) • rounds fired from small arms fire from exposed/unexposed positions • accuracy of BLUE Dismounted Infantry (small arms)

Force XXI Land Warrior
Measures of Performance
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LETHALITY	**9. Dismounted Infantry Ability To Incapacitate Out Of Sight Targets**	**MOE** • Total BLUE Dismounted Infantry casualties • % of Total BLUE Dismounted Infantry casualties from BLUE Dismounted Infantry (small arms) • Total OPFOR casualties • % of total OPFOR casualties which were out of sight targets due to BLUE DI fires • avg. rounds from BLUE DI fires/OPFOR casualty which were out of sight targets **MOP** • P(h) of BLUE Dismounted Infantry (small arms) on OPFOR out of sight targets	**DATA** • Total casualties to BLUE Dismounted Infantry • Casualties to BLUE Dismounted Infantry (small arms) • Total OPFOR casualties • # of Out of sight OPFOR targets which were casualties due to BLUE DI fires • rounds fired from BLUE DI at OPFOR out of sight targets • accuracy of BLUE Dismounted Infantry (small arms) on OPFOR out of sight targets
SENSING	**2. Target Detection And Identification Under Day, Night, Obscurants (Assumes Classification And Recognition Not Parameters For Dismounted Infantry Targets)**	**MOE** • increased % targets detected, identified **MOP** Under various conditions (day, night, obscurants) • avg. target detection, identification time • avg. range of detection, identification	**DATA** • # of detections, identifications • # detection opportunities • start/finish time detect, identification • range of detect, identification
SENSING	**11. Sqd./Plt. Leader Ability To Mark Targets**	**MOE** • increased OPFOR casualties at night from small arms fire • rounds/marked target casualty • rounds/unmarked target casualty **MOP** • % casualties = marked target • % casualties = unmarked target • avg. range of marked target casualties • avg. range of unmarked target casualties	**DATA** • OPFOR casualties at night from small arms fire • BLUE rounds at marked targets • BLUE rounds at unmarked targets • OPFOR marked target casualties • # OPFOR unmarked target casualties • range to each marked target casualties • range to each unmarked target casualties

Force XXI Land Warrior
Measures of Performance
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SENSING	**13. Mine Detection**	**MOE** • decreased total casualties due to mines **MOP** • time to negotiate areas with mine fields • % of total mines detected • detection message transmit times • warning message transmit times • avg. mine detection range	**DATA** • total casualties • casualties from mines • start/finish time negotiate minefield • total # mines present in mine field • # mines detected • time detection message initiated/received • time warning message transmitted/received • range to each detection
SENSING	**24. Laser/ Directed Energy Detection**	**MOE** • decreased # of BLUE casualties from OPFOR with lasers **MOP** • % time threat correctly detected • % detections that resulted in detection warnings • % detection warnings received • detection message transmit times • warning message transmit times • avg. detection ranges	**DATA** • # casualties from OPFOR equipped with lasers • # lasings • # lasings detected • # detection warnings generated / received • time warning message transmitted/received • range to each detection
SENSING	**28. Chemical, Biological, Flame, And Nuclear Detection**	**MOE** • decreased BLUE casualties from NBC • % BLUE casualties from NBC **MOP** • % time threat correctly detected • % detections that resulted in detection warnings generated • % detection warnings received • detection message transmit times • warning message transmit times • avg. detection ranges	**DATA** • casualties from NBC • total BLUE casualties • # detection opportunities # detections • # detection warnings generated / received • time detection message initiated/received • time warning message transmitted/received • range to each detection

Force XXI Land Warrior
Measures of Performance
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COMMUNICATIONS	**4. Soldier Identify Target Locations To Artillery, Aircraft, Mortars For Call For Fire: Range Determination, Azimuths, Automated Requests For Fire**	MOE • increase range and accuracy of identification, increased speed of reporting target location MOP • avg. difference between actual grid location and location reported by call for fire (CFF) • mean time to process CFF	DATA • actual and CFF reported location to each OPFOR target • time CFF prep initiated, time CFF sent, time CFF received
COMMUNICATIONS	**17. Sqd. Communication Capabilities**	MOE • increased communications range, reliability and speed MOP For voice/data: • # messages successfully transmitted • % messages successfully, unsuccessfully transmitted • avg. #, range and duration of successful message transmissions • clarification request rate	DATA • # and range of message transmissions attempted • #, range, duration of message transmissions received • # clarifications requested
SITUATIONAL AWARENESS	**10. Situational Awareness**	MOE • % blue casualties due to fratricide • increased knowledge about the battlefield situation MOP avg. difference between actual /reported number/location of OPFOR/BLUE forces	DATA • total blue casualties • blue fratricide casualties • actual/reported number/location of OPFOR/BLUE forces
SITUATIONAL AWARENESS	**20. Decision Making, Planning, And Reporting**	MOE • Reduced planning time, more accurate and faster reporting MOP • time to plan mission • avg. time to prep reports • difference between actual and reported data • time to transmit reports • clarification requests as a % of # of reports sent	DATA • start/finish time planning mission • start/finish time report prep • actual and reported data • time reports sent/ received • number of requests to clarify reports • number of reports sent

Measures of Performance

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SITUATIONAL AWARENESS	**22. Ability To Provide Video Intelligence Reports**	**MOE** • increased knowledge about the battlefield situation **MOP** • % video capture images successfully received • avg. range of video image capture transmissions • avg. time to send/receive video capture image	DATA • # video image capture attempted • # visual image capture transmissions received • range visual image capture transmissions received • time video capture image transmission sent/received
SITUATIONAL AWARENESS	**30. Medical Monitoring**	**MOE** • reduced mortality rate **MOP** • accuracy of injury assessment • injury data transmission times • mean casualty response time • % report transmissions received	DATA • actual and reported injury severity • time injury report transmission initiated/received • time casualty response initiated/completed • # injury report transmission attempted/received
MOBILITY	**5. Navigation Accuracy, Speed, Distance Covered**	**MOE** for day and night: • total mission time • total assault time • total cross country time • total mission, cross country distance mission, cross country, assault movement rate • percent of mission time at halt • % total casualties while at halt • frequency of halt • avg. duration of halt **MOP** • navigation error	DATA • start / finish time, location of mission • start/finish time of assault • start/finish time, location cross country movement • total casualties • total time duration at halt • casualties at halt • number of times soldier(s) at halt • start/finish time at halt • navigation error
SURVIVABILITY	**14. Bullet/Shrapnel Protection: Increased Survivability**	**MOE** • reductions in casualties **MOP** • total BLUE casualties • % BLUE casualties from indirect fire • % BLUE casualties from small arms fire • % BLUE casualties from grenades	DATA • total direct fire BLUE casualties • total indirect fire BLUE casualties • total grenade BLUE casualties

Force XXI Land Warrior
Measures of Performance
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SURVIVABILITY	**15. Quality And Duration Of Soldier Performance In Hot/Cold Environments**	**MOE** • increased Duration and improved Performance In Hot/Cold Environments **MOP** - # heat stress injuries/casualties - # cold related injuries/casualties - time lost to heat/cold injuries	DATA • body/skin temperature • heart rate • time become heat/cold casualty, time return the mission
SURVIVABILITY	**16. Ability To Block Or Deceive Enemy Target Acquisition Devices**	**MOE** • reduced range of target detection and identification by the enemy **MOP** • #, avg. range of BLUE systems acquired by OPFOR • % BLUE systems acquired by OPFOR	DATA • # of BLUE systems acquired by OPFOR • range to each BLUE entity acquisition by OPFOR • # blue systems in the mission
SURVIVABILITY	**21. Capability To Reduce Visual, Infrared, Radar, And Noise Signatures**	**MOE** Reduce Visual, Infrared, Radar, And Noise Signatures **MOP** • #, avg. range of BLUE systems detected by OPFOR • % BLUE systems detected by OPFOR	DATA • # of BLUE systems detected by OPFOR • range to each BLUE entity detected by OPFOR • # blue systems in the mission
SURVIVABILITY	**23. Laser/Directed Energy Protection.** **LW Components:** Laser Range Finder/Digital Compass/ GPS/Computer/Squad Radio (5KM Range)	MOE • reduction in laser casualties **MOP** • % BLUE casualties due to lasers • # BLUE casualties due to lasers	**DATA** • total BLUE casualties • BLUE casualties due to laser
SURVIVABILITY	**27. Chemical, Biological, Flame, And Nuclear Protection.**	**MOE** • reduction in casualties due to NBC **MOP** • BLUE casualties due to NBC • % BLUE casualties due to NBC	DATA • BLUE casualties due to NBC • total BLUE casualties

Force XXI Land Warrior
Measures of Performance
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MISCELLANEOUS	**18. Sustainment Of Food, Water, Ammunition And Batteries**	**MOE** • adequate ammo, food, water, power with reduced weight, logistic burden **MOP** • time soldier system is operational under • battle conditions without power resupply • food, water, battery, ammunition load	**DATA** • start/finish time of operation with out resupply • food, water, battery, ammunition load
MISCELLANEOUS	**19. The Probability Of Suppression Given A Shot**	**MOE** • OPFOR P(H) when being suppressed **MOP**	

Force XXI Land Warrior
Measures of Performance
DRAFT, January 1997

Source Documents
21st Century Land Warrior Exit Criteria, 21st Century Land Warrior Simulation Support Plan, Feb. 1994
Warrior Focus Support Plan, Dec. 1994
Generation II Soldier Data Dendritics July 1995
Land Warrior EOE Test Plan Aug. 1996
Land Warrior Capabilities Matrix (Draft) Sept. 1996

ANNEX R
DOR(J&L) RN 9812

July 1998

An Overview of the Soldier System M&S

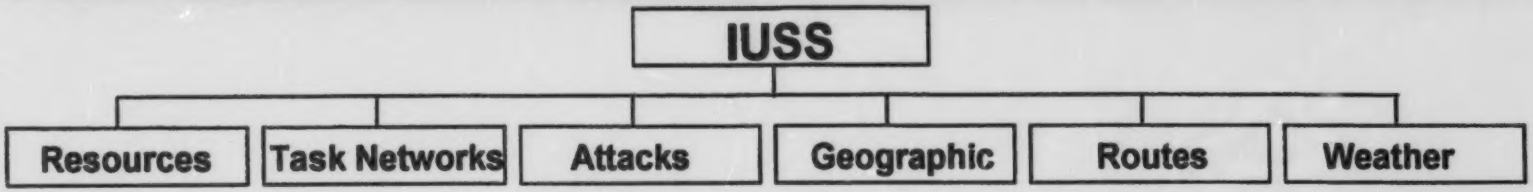
Overview of U.S. Soldier System Modeling

- IUSS
- MRTP
- SPE CAD
- CASTFOREM
- Janus
- Soldier Station

- Soldier System R&D Initiatives
- Distributed Interactive Simulation
- Training and Mission Rehearsal
- Operations Other Than War
- Military Operations in Urban Terrain

To support Soldier System decision makers by defining the combat worth of current and projected equipment through a simulation of individual and small unit combat operations in an integrated, realistic battlefield environment.

- Simulate individual small unit operability and survivability.
- Analyze current soldier system performance.
- Project future soldier system capabilities.
- Analytic virtual prototyping of soldier equipment and clothing.



Resources

- Units
  - Squad
  - Fire Team
- Personnel
  - Soldier
- Equipment
  - ...
  - Weapons
  - Sensors
- Resource Attribute
  - Heat Model
  - Chemical
  - State
  - Ballistic State
  - Weapon Capabilities
  - Sensor Capabilities
  - Armor
  - Body Data Base

Task Networks

- BOS-T
  - Move Tactically
  - Stationary
  - Defend
  - Attack
- Combat Resolution
- QNet
- Token

Attacks

- Indirect Fire (Off-Line effects Computation)
  - Ballistic
  - Chemical
- Direct Fire (On-Line effects Computation)
  - Ballistic

Geographic

- Vector Overlays
  - Rivers
  - Roads
- Text Annotations
- Terrain
  - IST CGF based
  - CTDB
  - X, Y & Z
  - Features
  - Obstacles
  - Line of Sight
  - Overlays

Routes

- Terrain Features
- Automatic
  - Type
  - Grade
  - Speed Limit
- Stochastic Barriers

Weather

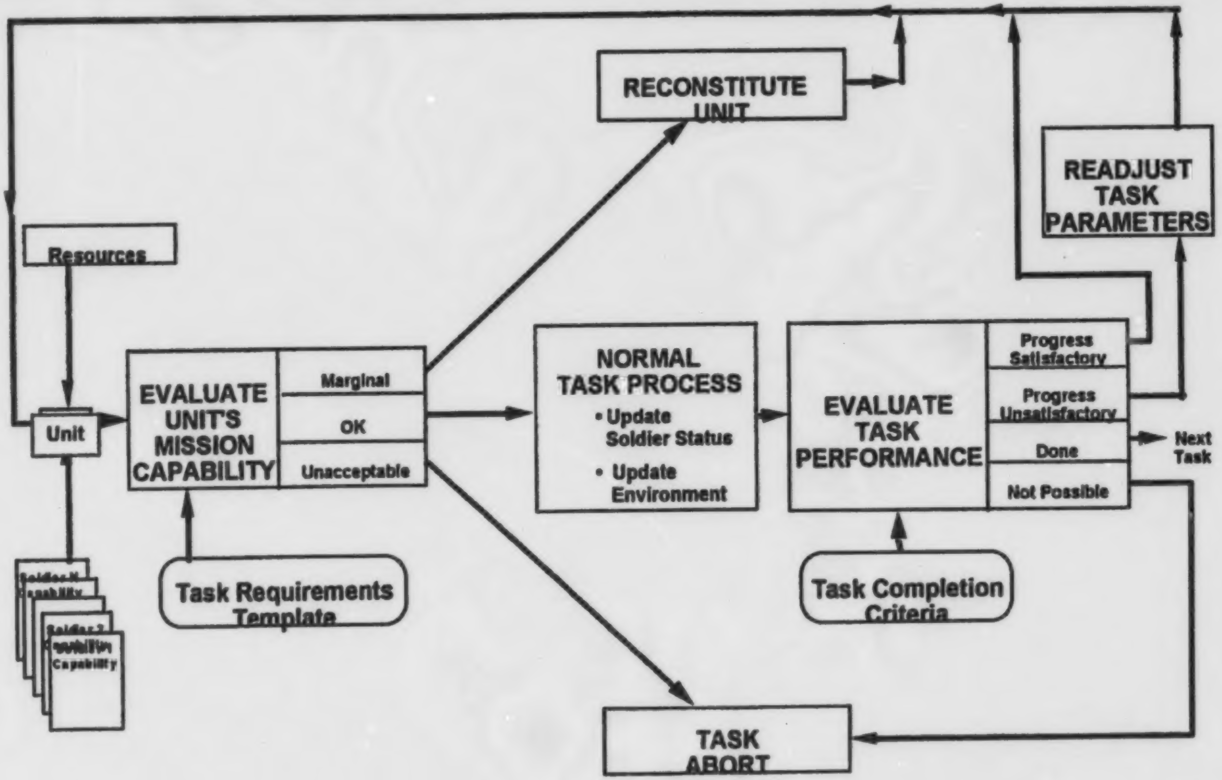
- Dynamic
  - Temperature
  - Humidity
  - Wind Speed & Direction
  - Cloud Cover

[illegible] S V2.2

- Accepts terrain in CTDB format
- Models MWS by associating a weapon with a bursting munition using the bursting weapon attribute
- Allows resources to experience a reactionary suppression to bursting munitions
- Changes the resource’s image according to posture changes

- Models different vision sensors using the Vision Sensor Attribute
- Resets the random seed to the original value for the project using the Reset Seeds button in the Simulation Control Box
- Models interaction with the terrain using the Stochastic Shield

[illegible] Loop


RECONSTITUTE UNIT
READJUST TASK PARAMETERS
Resources
Unit
EVALUATE UNIT'S MISSION CAPABILITY
Marginal
OK
Unacceptable
NORMAL TASK PROCESS
• Update Soldier Status
• Update Environment
EVALUATE TASK PERFORMANCE
Progress Satisfactory
Progress Unsatisfactory
Done
Not Possible
Next Task
Soldier N Capability
Soldier 2 Capability
Capability
Task Requirements Template
Task Completion Criteria
TASK ABORT

[illegible] of Contact

Soldier Systems Command

John O'Keefe
US Army Soldier Systems Command Natick Research, Development and Engineering Center
Natick, MA 01760
phone: (508) 233-4881
fax: (508) 233-4154
email: jokeefe@msis.dmso.mil

DMISTIAC Service Center Orlando

Jim Hendris
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Orlando, FL 32826-0544
Phone: (407) 249-4712
Fax: (407) 658-5059
email: dis-order@sc.ist.ucf.edu
WWW: http://132.170.192.52/

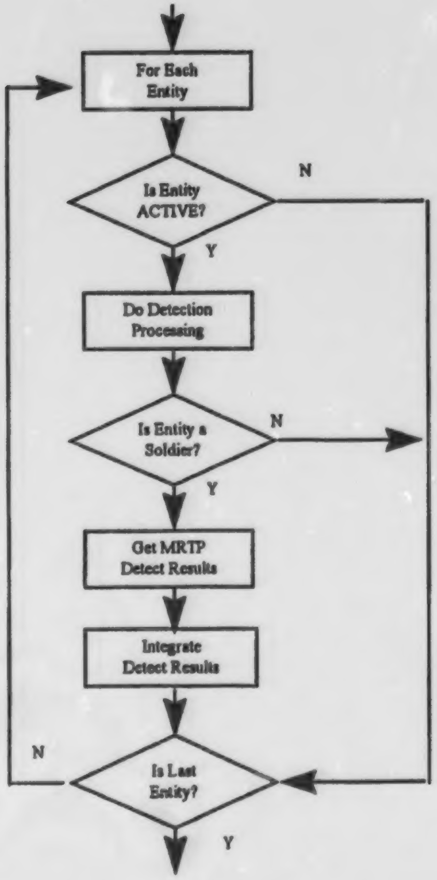
Micro Resolution Terrain Processor
(MRTP)

- High resolution simulation to support individual combatant research and development
  - Analytic simulation
  - Virtual prototyping environment
  - Test bed to understand effects of different levels of terrain resolution
- Tools to assess effects proposed equipment changes have on survivability and performance

- 10 X 10 kilometer 1 meter resolution
  - – Elevation & features 32 MB
- 10 X 10 kilometer 0.3 meter resolution
  - – Elevation - 1,800 MB
  - – Trees up to 4,560,000

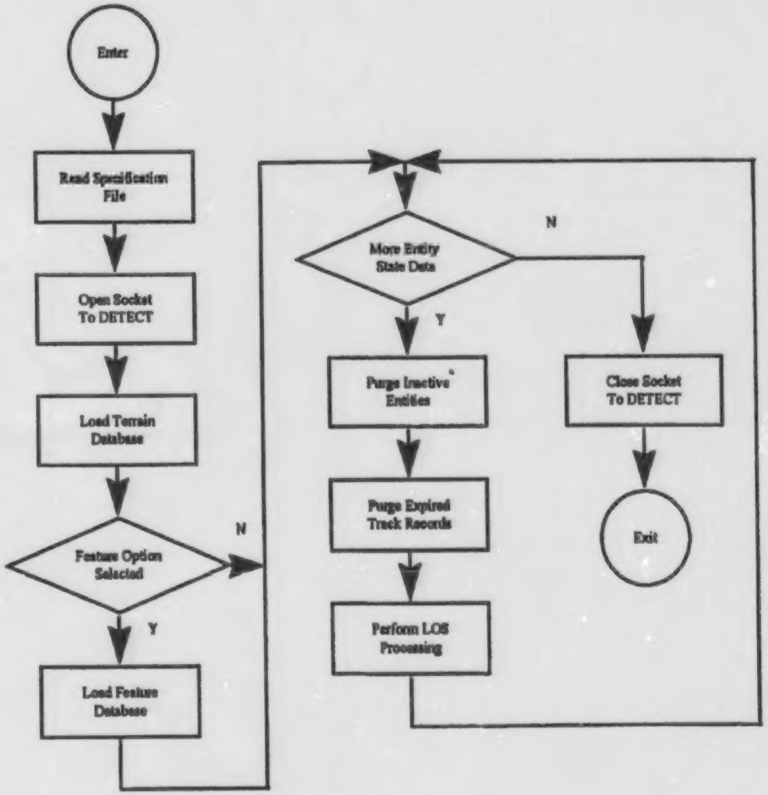
- Provide a high resolution “plug-in” capability
- Load and use 0.3 meter DMA format terrain data bases
- Load and use feature data bases
- Operate faster than real-time
- Perform simulation of individual combatant
  - search
  - detection, and
  - tracking

[illegible] Overview
[illegible] Detection Function



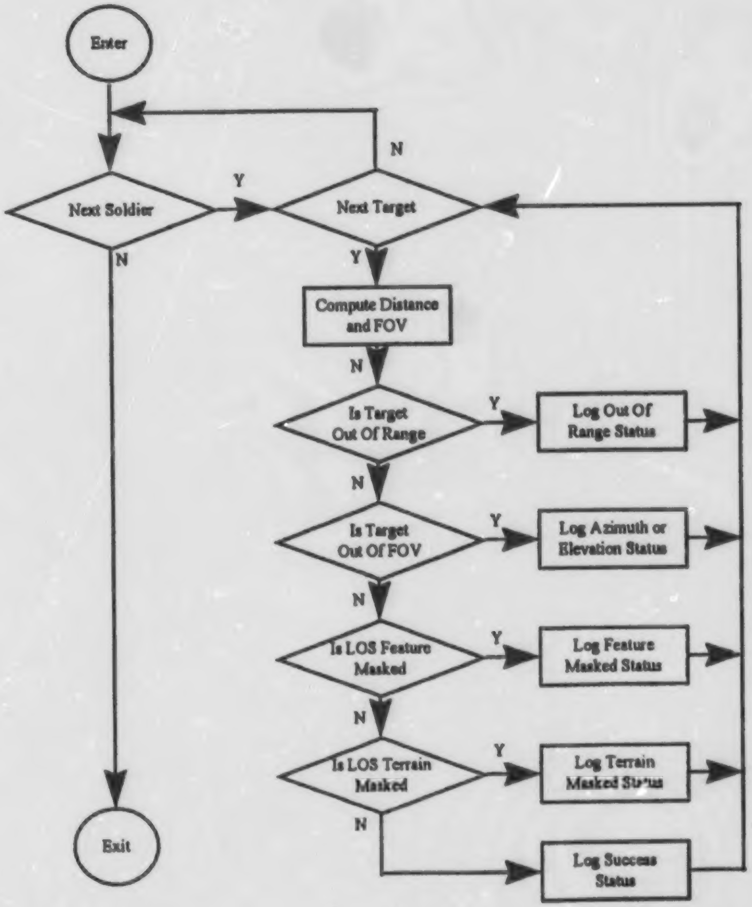
For Each Entity
Is Entity ACTIVE?
N
Y
Do Detection Processing
Is Entity a Soldier?
N
Y
Get MRTP Detect Results
Integrate Detect Results
N
Is Last Entity?
Y

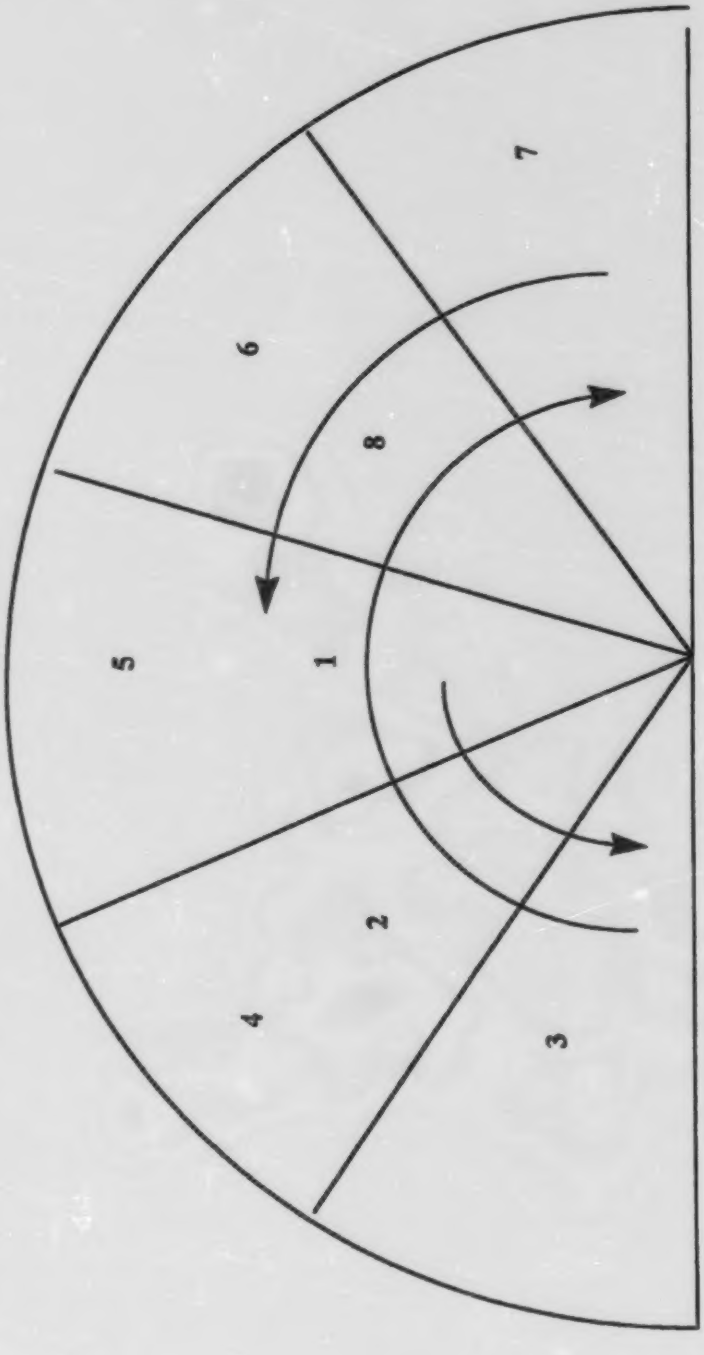
[illegible] Overview


Enter
Read Specification File
Open Socket To DETECT
Load Terrain Database
Feature Option Selected
Y
N
Load Feature Database
More Entity State Data
Y
N
Purge Inactive* Entities
Purge Expired Track Records
Perform LOS Processing
Close Socket To DETECT
Exit

[illegible] Overview

[illegible]


Enter
Next Soldier
Y
N
Next Target
N
Y
Compute Distance and FOV
N
Is Target Out Of Range
Y
Log Out Of Range Status
N
Is Target Out Of FOV
Y
Log Azimuth or Elevation Status
N
Is LOS Feature Masked
Y
Log Feature Masked Status
N
Is LOS Terrain Masked
Y
Log Terrain Masked Status
N
Log Success Status
Exit

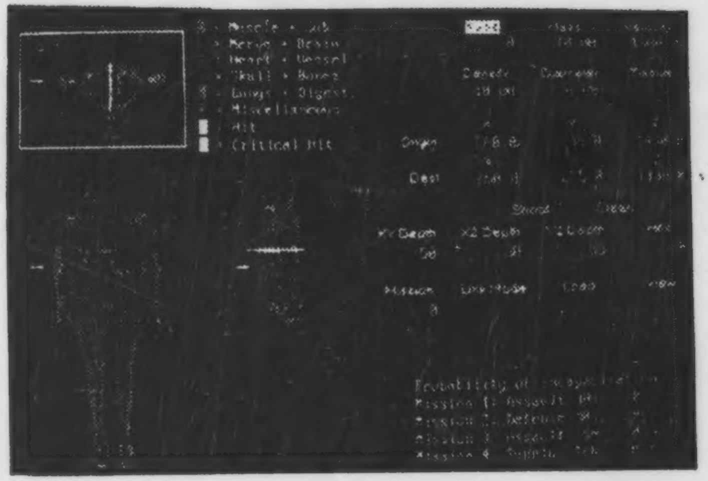


- MRTP provides high resolution individual combatant simulation of
  - visual search,
  - target detection, and
  - target tracking
- MRTP provides a “plug-in” capability to support future individual combatant R&D

[illegible] System

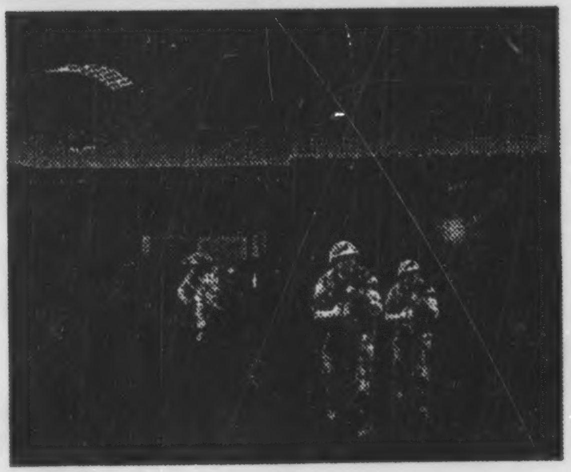
Description

- ➢Engineering level detail simulation of protective system performance/failure and human wounding
- ➢Level of detail modeled
  - – Insults
    - – Bullets
    - – Flechettes
    - – Blunt trauma
  - – Body armor
    - – Fabric
    - – Ceramic/metal plates
  - – Anatomy
    - – Articulated anatomical model
    - – 80,000 voxel representation of 250 tissue types
    - – Anatomically scaleable
- ➢Runs on Personal Computer under MSDOS


Nerve + Brain
Heart + Vessel
Skull + Bones
Lungs + Digest.
Miscellaneous
Hit
Critical Hit
Origin
Dest
X1 Depth
X2 Depth
Mission

- **Status**
  - ➢Developed under a Small Business Innovative Research (SBIR) program contract with Mission Research Corp.
  - ➢Developed program intellectual property of Mission Research Corp. until 1999
  - ➢Has been used to support analytic projects

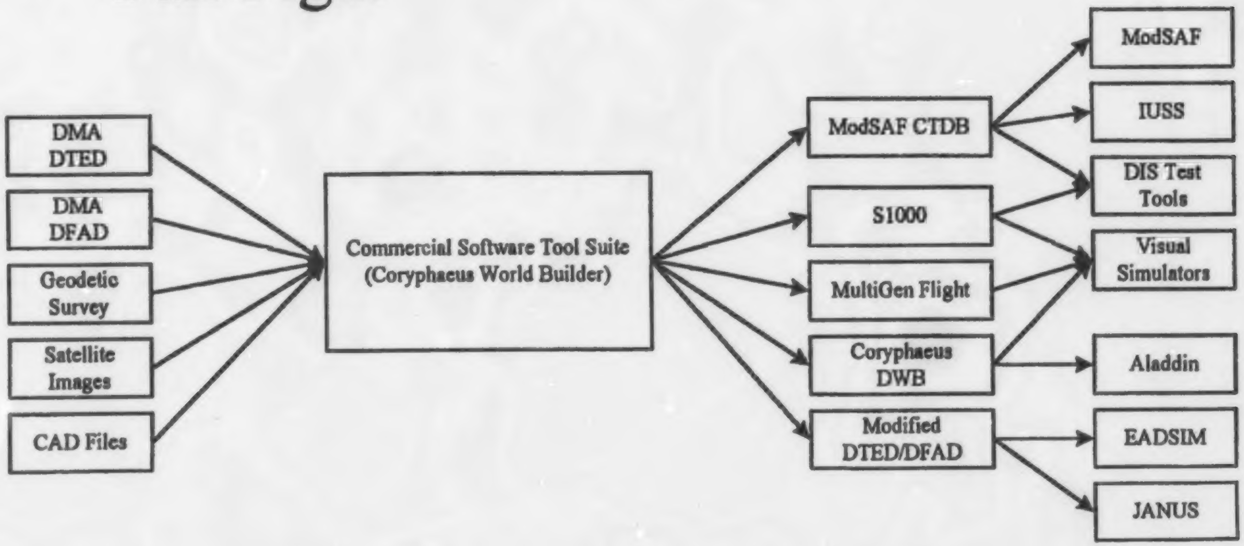
Natick Vision - Full Soldier Immersion Into The DIS Environment



- Full Immersion with Performance Quantification and Connection to:
  - Environmental Chambers
  - Biomechanical Laboratory
- 3 Dimensional Realistic Stealth
- Virtual Prototyping of Soldier Items to Support Acquisition Improvement
- Multiple Terrain Resolution
- Linked to Defense Simulation Internet (DSI)
- 2D Photo Realistic Stealth
- High Resolution Simulation of
  - Dismounted Infantry (IUSS)
  - Vehicles & Aircraft (ModSAF)
  - Air Drop Technologies
- Army Standard Combat Models
  - Janus
  - Extended Air Defense Simulation

Why Do We Care?

- Consistent defendable analysis
- Analysis of field test results
- “Fair Fight”


DMA DTED
DMA DFAD
Geodetic Survey
Satellite Images
CAD Files
Commercial Software Tool Suite (Coryphaeus World Builder)
ModSAF CTDB
S1000
MultiGen Flight
Coryphaeus DWB
Modified DTED/DFAD
ModSAF
IUSS
DIS Test Tools
Visual Simulators
Aladdin
EADSIM
JANUS

ANNEX S
DOR(J&L) RN 9812
July 1998

Dismounted Infantry Representation in Combined Arms Support Task FORce Evaluation Model CASTFOREM

John Galloway

Acting Division Chief, Dismounted Combat Division

TRADOC Analysis Center -White Sands Missile Range

White Sands Missile Range, New Mexico 88311

gallowaj@trac.wsmr.army.mil

CASTFOREM

- Brigade Level Model
- Stochastic Simulation
- Combined Arms representation
- Subject Matter Expert Logic is embedded within Decision Tables
- Excellent for System level analysis
- Used in Cost and Operation Effective Analysis for the last nine years.

Background

- **Close Combat Model Improvement Program** - Upgrade constructive models CASTFOREM and Janus.
- **Land Warrior COEA MSII** - Initial dismounted infantry modeling using CASTFOREM and Janus. Lead to the development of the Soldier Station.
- **Soldier Station Development** - An analytic tool developed to provide insights into the dismounted soldier issues being address in the Land Warrior/Force XXI Land Warrior Programs.

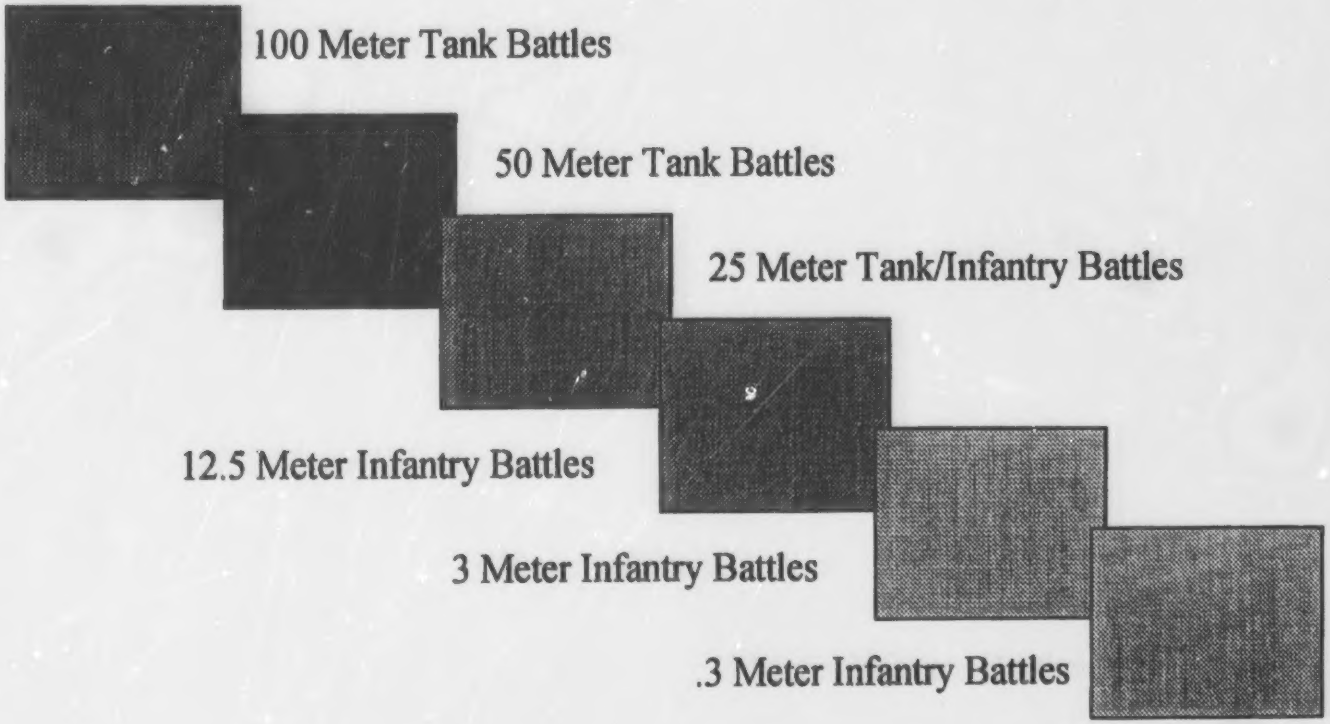
Scenarios / Vignettes

- **Warrior Focus Advanced Warfighting Experiment (WF AWE)** - Five vignettes; Squad Ambush, Squad Movement to Contact, Platoon Attack, Platoon Defense, Company Attack. The Platoon Attack and Company Attack were used in the Objective Individual Combat Weapon (OICW) study.

- **Force XXI Land Warrior (FXXILW) Early Operational Experiment (EOE) Vignettes** - These scenarios will be used in the evaluation of the FXXILW program. Developed in Janus and then used in Soldier Station and CASTFOREM as applicable.

- **HRS 38.2 Dismounted Infantry** - This will be an extension of the main battle focusing on the close battle with the dismounted infantry. Will be ready for use in FY97.

Terrain Evolution



100 Meter Tank Battles

50 Meter Tank Battles

25 Meter Tank/Infantry Battles

12.5 Meter Infantry Battles

3 Meter Infantry Battles

.3 Meter Infantry Battles

Foxhole Representation

- Explicit - Detailed representation:
  - ✓ Width, Length, Height, Type of Cover
  - ✓ Size, Location, Field Of View (FOV) from Firing Ports
- Implicit - Used in two roles,
  - ✓ Foxholes - Hastily dug
  - ✓ Terrain Features
    - Depressions
    - Ground Clutter
    - Stochastic draw to determine percentage of cover

Buildings Representation

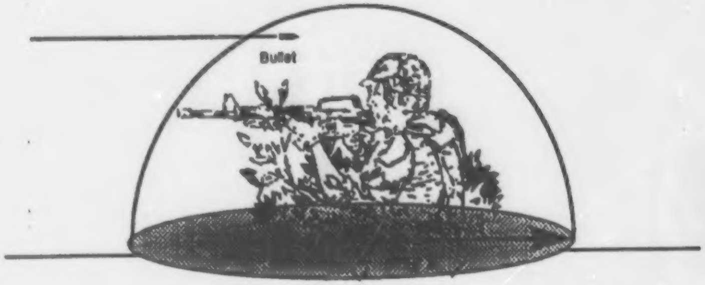
- Research effort
  - ✓ Buildings configuration
    - Single story
    - Doors, windows, interior rooms, halls
  - ✓ Buildings are part of the terrain
  - ✓ Line of Sight is blocked within from room to room
  - ✓ Cannot fire through walls
- McKeena MOUT site, Fort Benning, GA
- Will use for Objective Individual Combat Weapon Analysis

Sensors / Weapons

- Thermal Weapon Sights
  - ✓ Heavy
  - ✓ Medium
- Image Intensifer
- Eyes
- Binoculars
- Red Dot
- Combat Optics
- Anti-Tank Weapon Sensors

- Sensors and Weapon Accuracy linked together
- M16
- M203
- M249
- M60
- Objective Individual Weapon System
- Anti-Tank Weapons
- Grenades / Claymore

Direct Fire Suppression

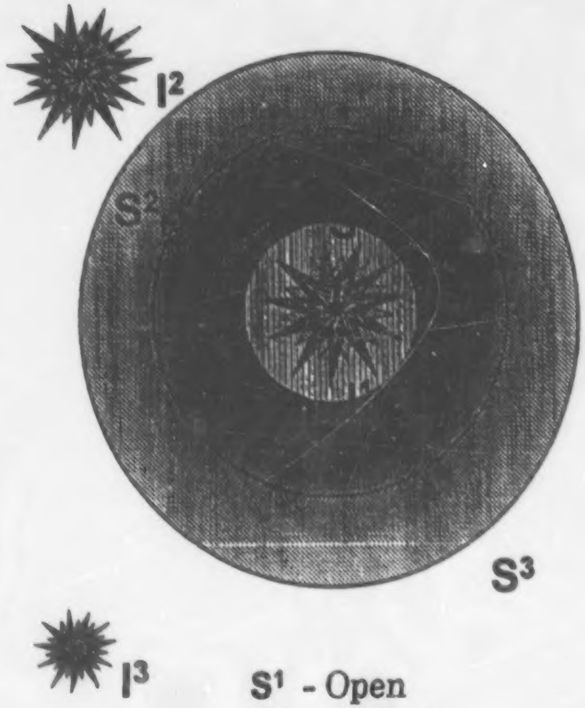


The suppression radius is user defined and is defined for each vignette and type of soldier. The radius will form a hemisphere around the soldier.

When the round passes within the suppression hemisphere the soldier will take a suppression posture associated with that type of soldier. The amount of time of suppression is unique for each vignette and soldier.

Indirect Fire Suppression

Logic



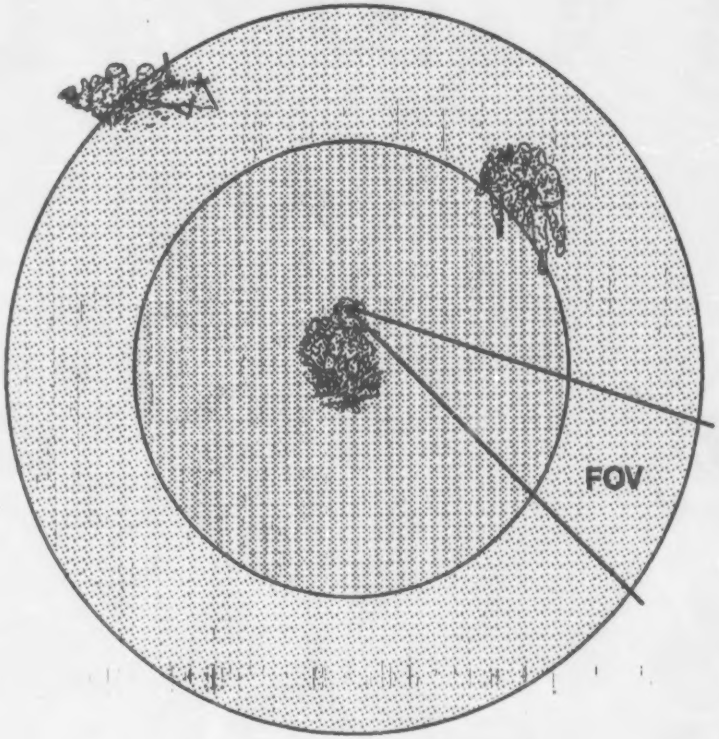
S^1 - Open
S^2_f - Foxhole
S^3 - Outside suppressive area

Round Impacts - Model assess the Soldiers within the lethal area of the round - If soldier is not killed then he will be suppressed by rules stated below. If outside the lethal area but within the area of suppression soldier will be suppressed. Allows for continuous suppress times, i.e. S^2_f which is effected by I^1 and I^2.

S^1 - Go prone for "X" seconds
S^2_f - Go down in Foxhole for "X" seconds
S^3 - Continue with Mission

I^1 - Impact point 1 at T^1
I^2 - Impact point 2 at T^2
I^3 - Impact point 3 at T^3

Queues

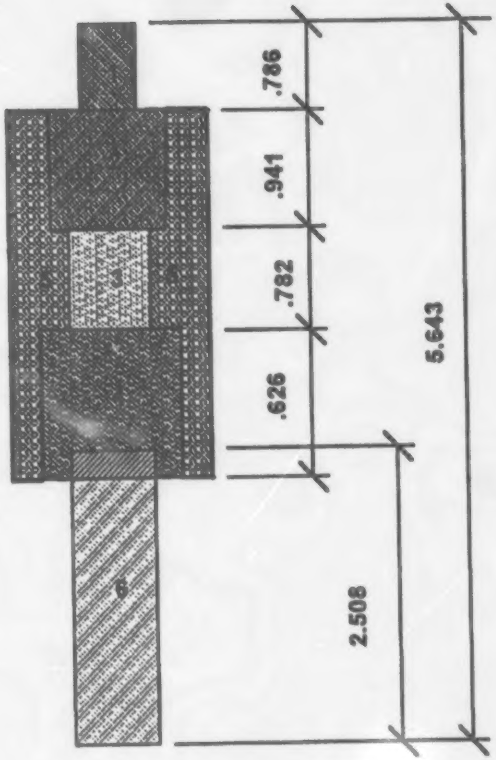


Two type of Queue Ranges
    Movement Range (Red)
    Firing Range (Blue)

Both are independently defined. Inputs are target type Vs range and munitions being fired Vs range.

When the boundary has been breached, the soldier will look in the direction of the target. An acquisition must be obtained before the target is engaged. The acquisitions are not automatic, if a target is not found the soldier returns to the previous FOV and continues to search.

Soldier Representation



Regions

1 - Head and Neck
2 - Thorax
3 - Abdomen
4 - Pelvis
5 - Upper Extremities
6 - Lower Extremities

Postures

1 - Standing
2 - Crouching
3 - Kneeling
4 - Prone
5 - Foxhole

Body armor* can be placed on any area, top down, with different degradation factors for each area.

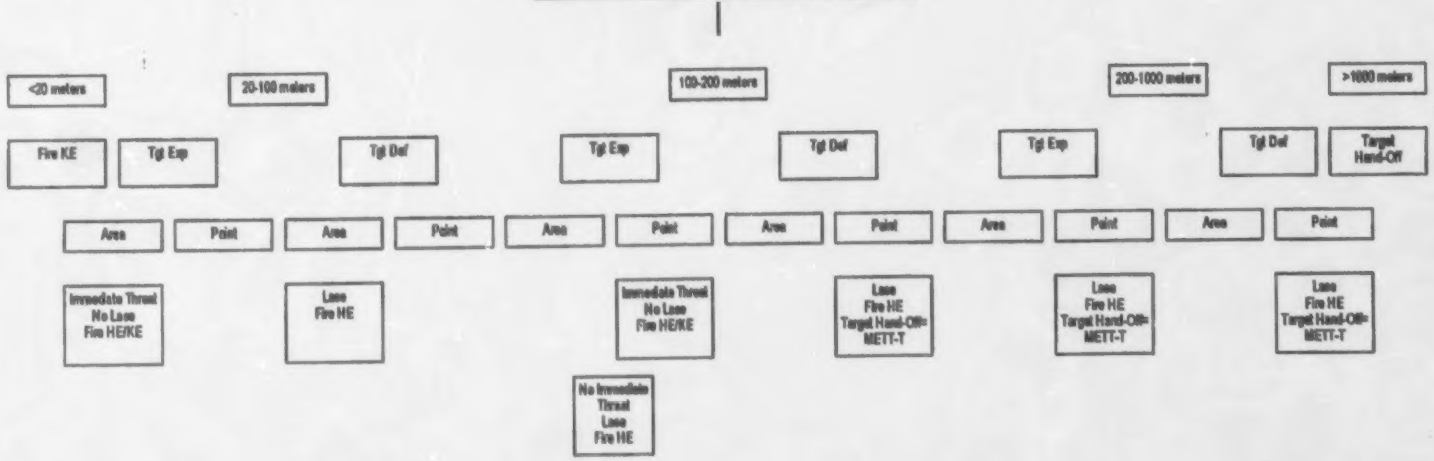
Volumes are cylindrical

Kill types per Area

Mobility Only - Area 6
Fire Power Only - Area 5
Catastrophic - Areas 1, 2, 3, 4

Objective Individual Combat Weapon (OICW)

OICW Decision Tree



<20 meters

20-100 meters

100-200 meters

200-1000 meters

>1000 meters

Fire KE

Tgt Exp

Tgt Def

Tgt Exp

Tgt Def

Tgt Exp

Tgt Def

Target Hand-Off

Area

Point

Area

Point

Area

Point

Area

Point

Area

Point

Area

Point

Immediate Threat
No Lase
Fire HE/KE

Lase
Fire HE

Immediate Threat
No Lase
Fire HE/KE

No Immediate Threat
Lase
Fire HE

Lase
Fire HE
Target Hand-Off=
METT-T

Lase
Fire HE
Target Hand-Off=
METT-T

Lase
Fire HE
Target Hand-Off=
METT-T

Notes:
Primary Munition is HE
KE used only when it is impractical to use HE
Battle Sights:
  KE-300 Meters
  HE-100 Meters
Engage enemy when he has gone to ground
Number of rounds per Engagement
  Point Target - 1 round
  Area Target (10X50 Meters) - 3 rounds

Rounds Available:
HE
  5-8 round Mag.
KE
  5-30 round Mag.

KE round max range is 580 Meters

Information obtained from the DBBL

Tactics, Techniques and Procedures

- Vignette Specific
- Military Used Extensively in Vignette Development
- Detail Logic
  - ✓ Maneuver
    - 3-5 Second Rush
    - Formations
  - ✓ Weapon System
- Suppression
  - ✓ Direct
  - ✓ Indirect

Summary

- CASTFOREM can be used in Dismounted Infantry studies.
- CASTFOREM's representation of Dismounted Infantry will continue to mature.
- Represent present and future weapon with a great amount of detail.
- MOUT is still in the investigation stage but with no real plans for detailed representation within CASTFOREM.

Janus

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Janus

- Brigade Level Model
- Used in Cost and Operational Effectiveness Analysis, Training, Test Exercise Driving, and Operations Rehearsals
- Man in Loop
- Algorithms & Human Interface Logic
- Tactics, Techniques, and Procedures
- Individual Combatant Representation

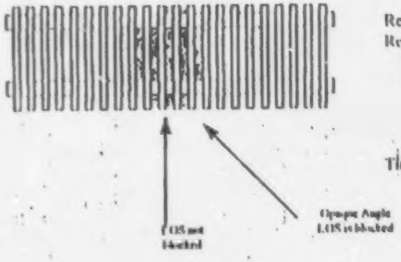
Individual Representation

- Small Arms (M16, M203)
- Target Acquisition Sensors
- Individual or Aggregate
- Routes
  - ✓ Specified or Modified
- Indirect Fire
- Probability Line Of Sight
- Three Postures

Unit Representation

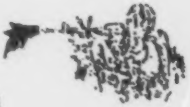
- Aggregate of specific systems
- Formations
- Some Military Operations in Built-up Area
- Gamer manipulates individual or aggregate
- Muzzle Flash Engagements
- 3-5 Sec Rushes in Assault mode
- Minefield / Breaching
- Suppression

Obstacles



Represent all military Obstacles
Representation man made obstacles
  Walls
  Fences
    Wire
    Picket
    Stone
  Examples as characterized by data
Time delays to clear / breach an obstacle

Firing at Muzzle Flash



Probability of Detection muzzle flash 0.5
- Flash within Area of Interest
- LOS exists

Flashes are listed as targets
- Lower Priority target
- Discarded after 12 seconds

Engagement
- Fire once, search, fire again

Assessment
- Kill probability 0.001
- Suppression probability 0.80

Future Enhancements

- Non Lethal Representation
- MOBA
  - ✓ Bldg. Rubbling (to be in 7.0)
  - ✓ Rooms
  - ✓ Clearing of Bldg.
- Illumination
- Heterogeneous Aggregation (to be in 7.0)

Summary

- **Janus can be used in Dismounted Infantry studies.**
- **Janus representation of Dismounted Infantry will continue to mature.**
- **Tactics, Techniques and Procedures are the areas were Janus is a leader in the analytic models.**
- **MOUT can be investigated on a limited basis.**

Polygonal Terrain

Vegetation
- 7 Types
- Height
- PLOS (per 25 meters)
- Speed degradation factors (wheeled, tracked, footed)

Urban
- 7 Types
- Height
- PLOS (per 25 meters)
- Speed degradation factors (wheeled, tracked, footed)

Roads
- 20 Types
- Class (primary, secondary)
- Width
- Speed degradation factors (wheeled, tracked, footed)

Rivers
- 20 Types
- Class (primary, secondary, or lake)
- Width
- Crossing times (wheeled, tracked, footed, or amphibious)

Fences
- 20 Types
- Height
- PLOS (perpendicular to fence)
- Opaque angle (degrees)
- Crossing or clearing times

Generic Areas
- 20 Types
- Height
- PLOS (per 25 meters)
- Speed degradation factors (wheeled, tracked, footed)

Generic Strings
- 20 Types
- Width
- Height
- PLOS (perpendicular to string)
- Crossing or clearing times

Buildings
- 99 Types
- Number of Floors
- Construction type
- Opening (percent of exterior area)
- Fortification Times
- Total number of rooms

ANNEX U
DOR(J&L) RN 9812
July 1998

VALIDATION AND DEVELOPMENT OF A DISMOUNTED MOVEMENT SIMULATION MODULE

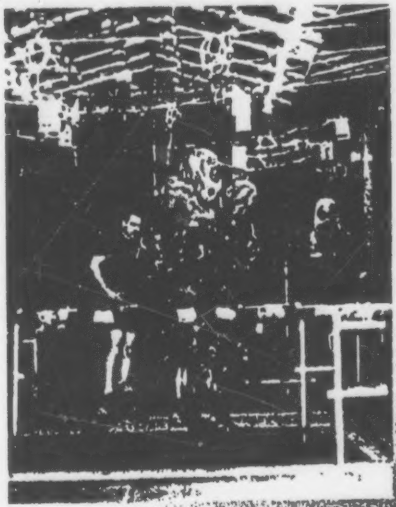
George Mastroianni, Ph.D
U.S. Army Natick Research, Engineering and
Development Center

Dismounted Combatant Mobility

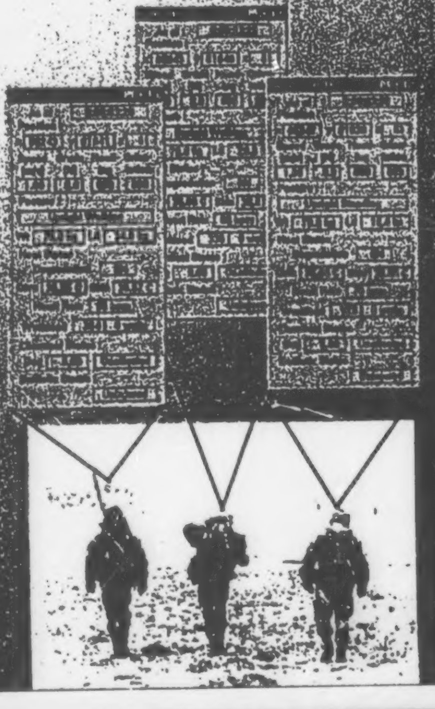
- st Module of the IUSS
  - Fundamental to Dismounted Operations
  - Fairly Well Understood
  - Accessible Data
  - Allowed examination of soldier load issues
  - Incorporated detailed physiological models of the individual combatant

Applying Laboratory Models to Operational Movement

- **Laboratory**
  - Driven by experimental protocols
  - Careful factor control
  - Precise measurement of inputs / outputs



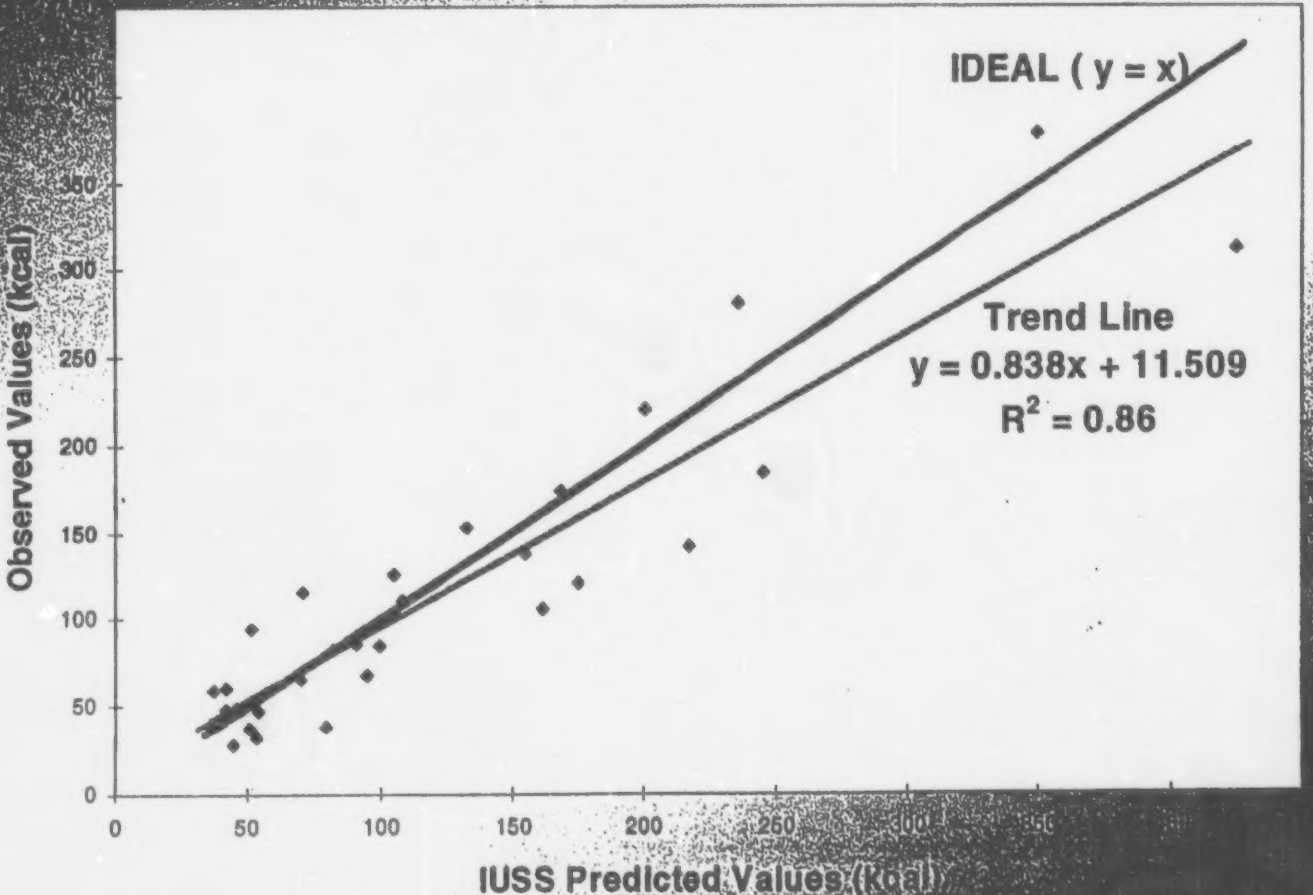
- **Field**
  - Individuals self-regulate in response to METT-T
  - Confounding by both known and unknown factors
  - Observations irregular, missing, estimated



Yosemite Mobility Rates Study

- Designed as a Metabolic Workload Study to Assess Ration Requirements
- A Field Study with Marines & Special Forces in Mountainous Terrain
- Estimated March Rate, Terrain Grade, and Individual Energy Expenditure Over 70 Mile Route

Validation of IUSS Energy Expenditure Predictions

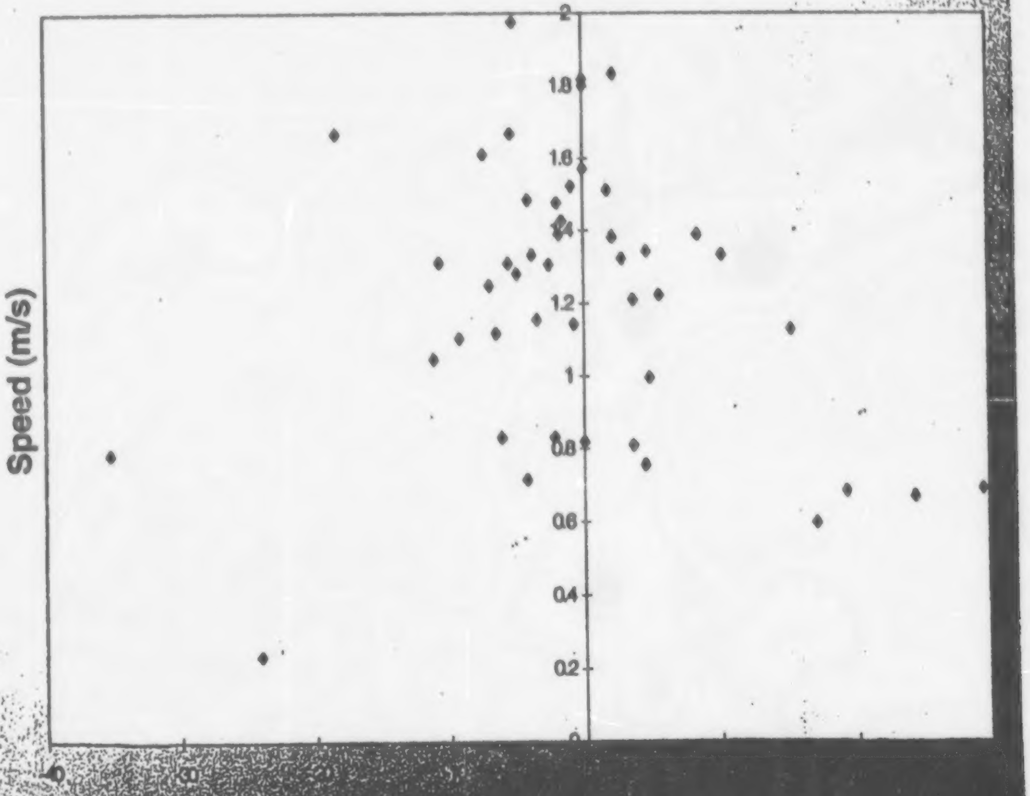


Mobility Study Data: Grade vs. Speed

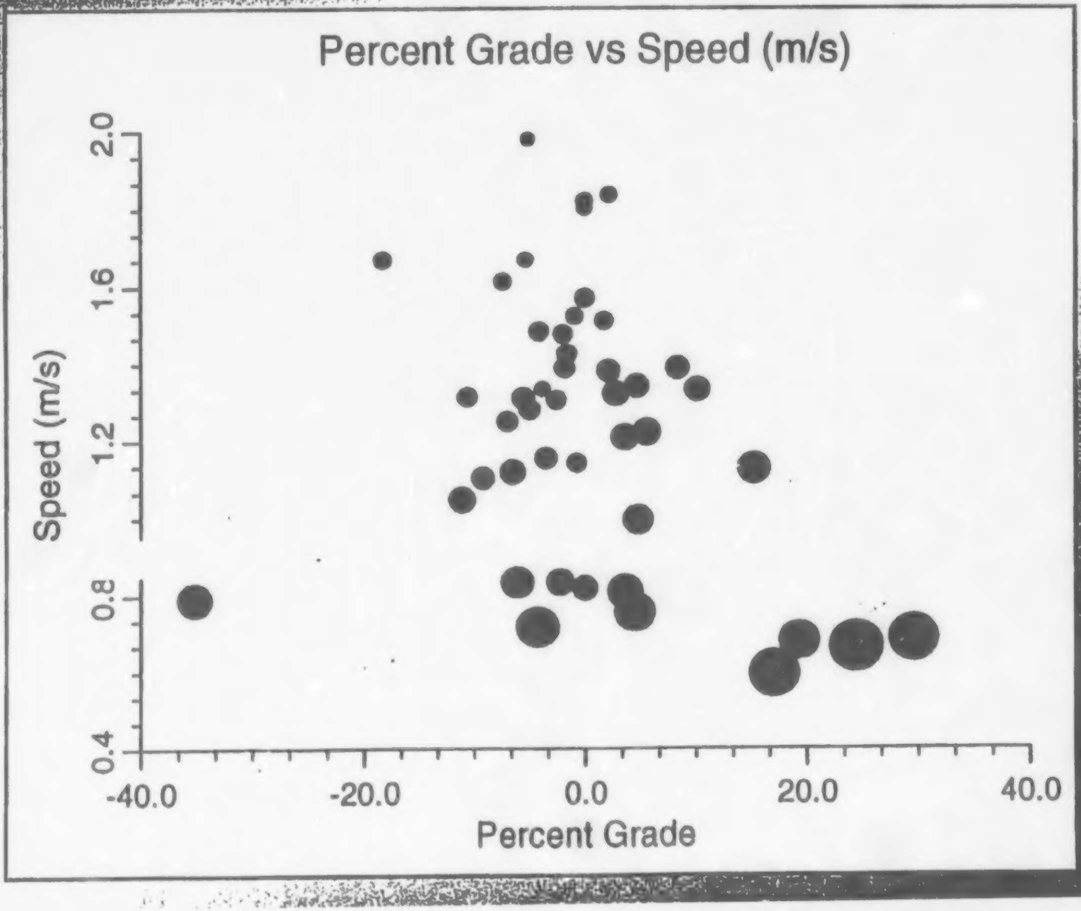
Preliminary Assessment:

Grade Alone is a Poor Predictor of Speed

Speed Vs Percent Grade



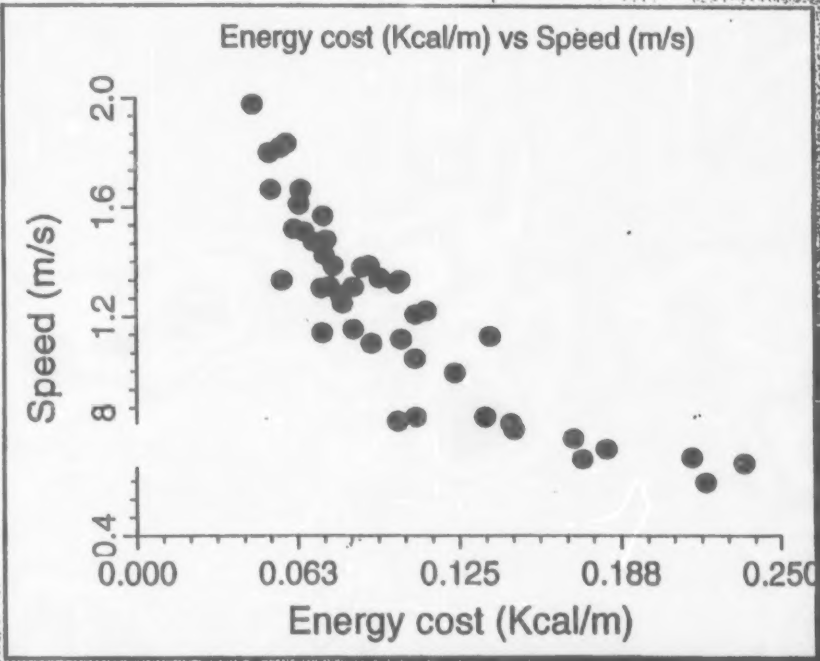
However, When Energy Expenditure is Considered



Percent Grade vs Speed (m/s)

Energy Cost vs. Speed

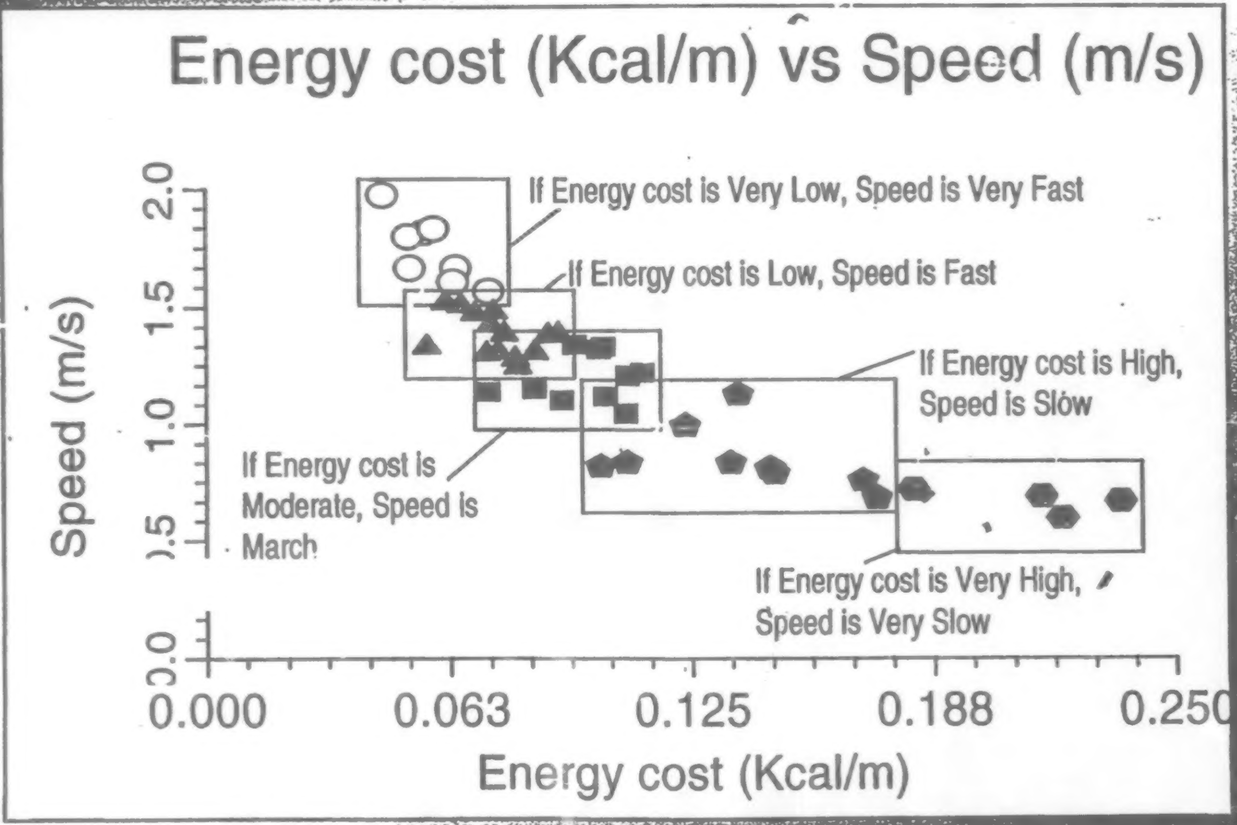
- Energy Expenditure Is a Better Predictor of Speed than Grade
- Next Step is Classification of Speed and Energy Expenditure into "Adjective" sets



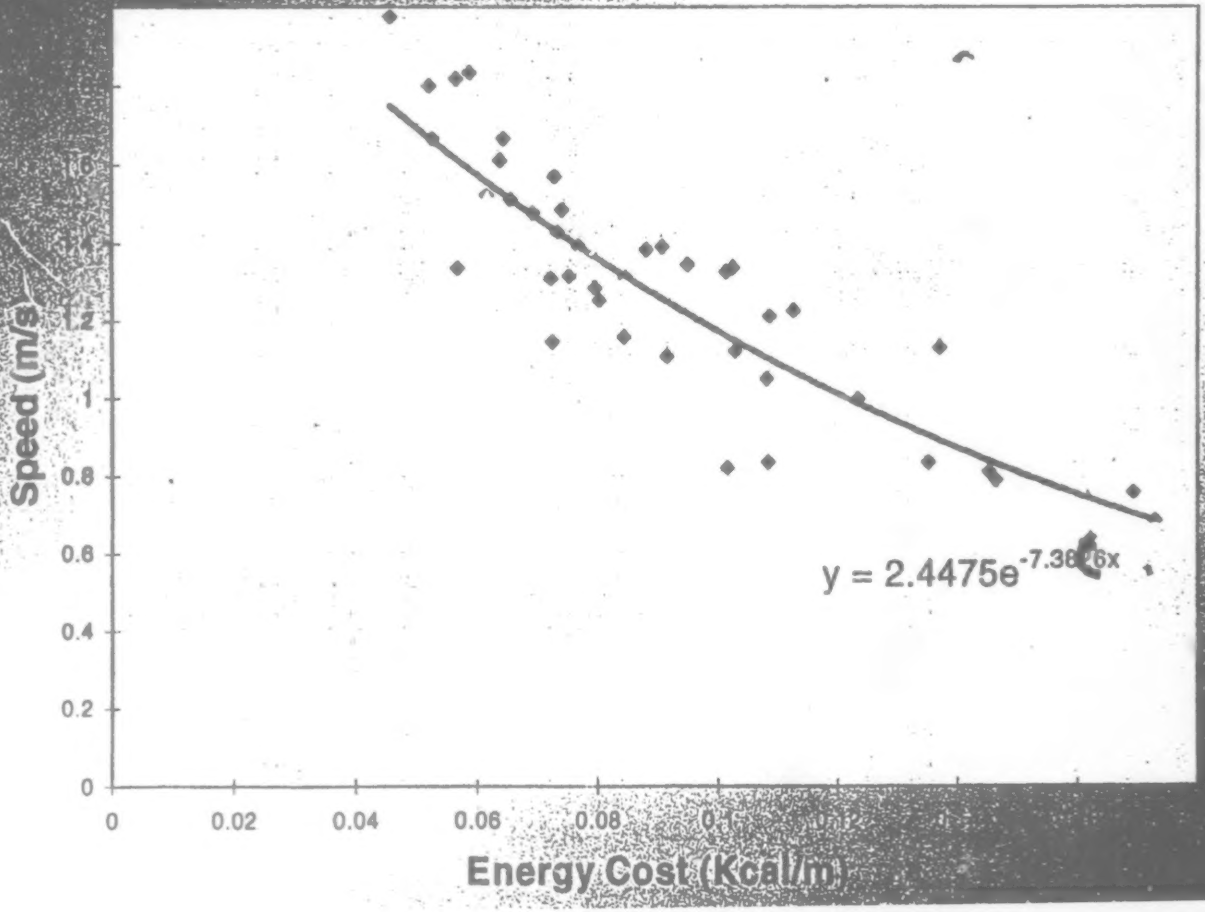
Next Steps

- Seek Measurable Predictors of Energy Cost
  - **Grade (dz/ds),**
  - **Grade variation (d^2z/d^2s),**
  - **Surface Type,**
  - **Vegetation**
- Incorporate Inference Engine with Feedback IUSS
- Expand to Consideration of Operational

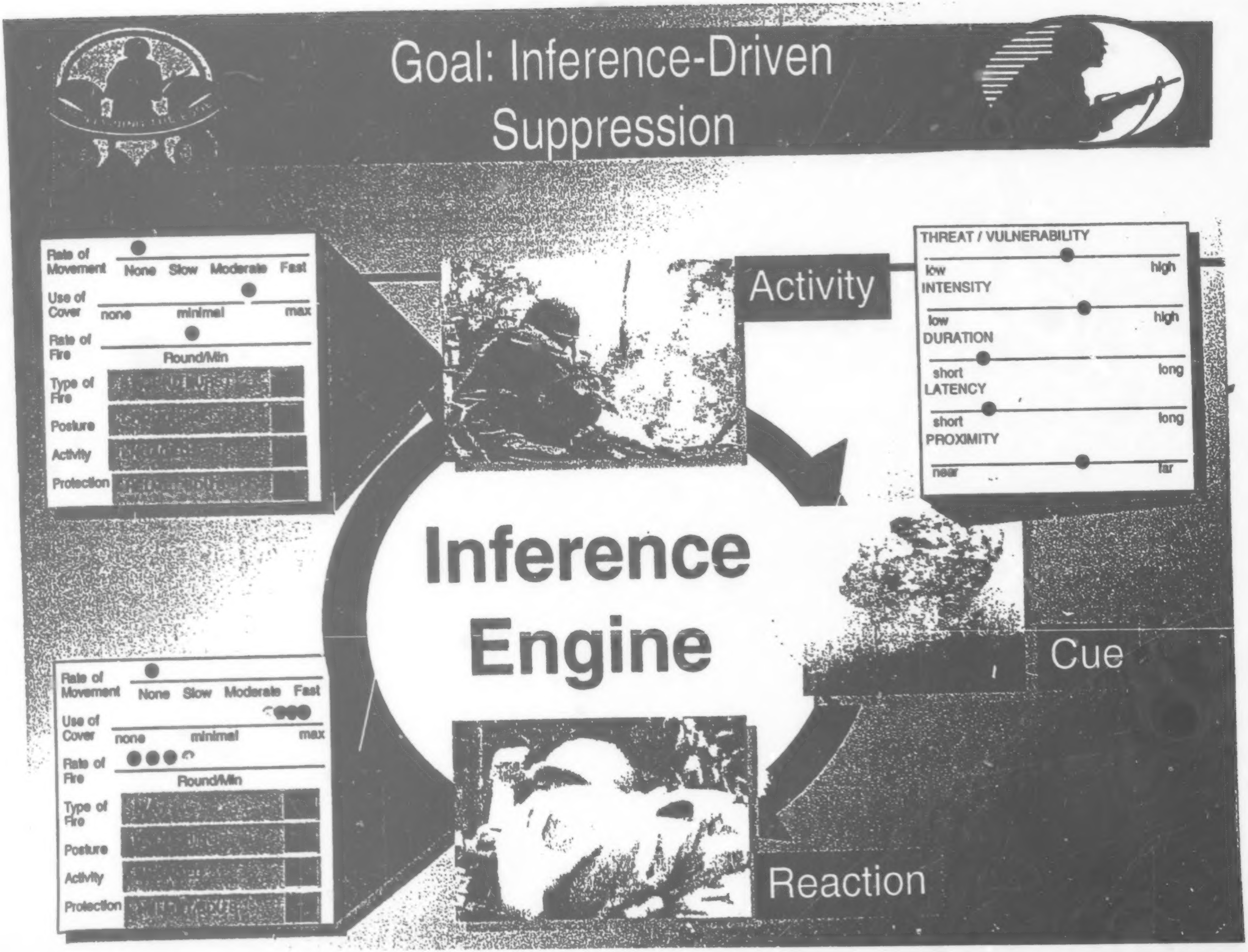
Rules Derived From Fuzzy Clusters


Energy cost (Kcal/m) vs Speed (m/s)

Speed Prediction Comparisons



Correlation of Observed with "Fuzzy" Speeds is 0.91



Goal: Inference-Driven Suppression

Rate of Movement: ● None, Slow, Moderate, Fast

Use of Cover: none, minimal, ●, max

Rate of Fire: ●, Round/Min

Type of Fire

Posture

Activity

Protection

Activity

THREAT / VULNERABILITY: low, ●, high

INTENSITY: low, ●, high

DURATION: short, ●, long

LATENCY: short, ●, long

PROXIMITY: near, ●, far

Inference Engine

Cue

Reaction

Rate of Movement: ● None, Slow, Moderate, Fast ●●●

Use of Cover: none, minimal, max

Rate of Fire: ●●●, Round/Min

Type of Fire

Posture

Activity

Protection

Tekapo Manoeuvres Overview

29 January 1997

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Objectives

- To develop and implement an analytical framework against which force structure and capability requirement options will be benchmarked and evaluated
- To establish a dynamic and realistic capability development programme that will ensure the appropriateness of the Army's warfighting capability

Intended Process

- Develop analytical process/framework
  - Acquire or develop analytical tools and methods eg. IUSS, CAEN and others
  - Information search concerning:
    - availability of relevant information through international fora
    - industry capabilities
- Implement an ongoing process of evaluation and introduction of appropriate changes to Army capabilities

Key Elements

- Exercises
- Concept and equipment trials
- Modelling and simulation
- Actual operations

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US SOLDIER SYSTEM LAND WARRIOR PROGRAM

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Date sent: **Wed, 29 Jan 1997 18:26:48 -0500**
To: **lwillner@dms-hp.ora.dnd.ca**
From: **"John A. O'Keefe IV" <jokeefe@triton.dmso.mil>**
Subject: **World Wide Web Address of Potential Interest**
Copies to: **jokeefe@triton.dmso.mil**

Lisa

The following is a list of World Wide Web (WWW) address that work shop attendees might find useful/interesting.

US Defense Modeling and Simulation Office http://www.dmso.mil

<paraindent><param>out</param> Information on Higher Level Architecti and US DoD M&S guidance/policies

US DoD M&S Definitions

Links to JMASS, JSIM, JWARS home pages

US Army Modeling and Simulation Office
http://www.misma.army.mil:443/amso/

</paraindent> US Army M&S Policy and Guidance

Documents describing Verification& Validation US style

RD&E Net http://rde-net.sc.ist.ucf.edu/

Information about US Research Development and Engineering M&S activities

Date sent: Thu, 30 Jan 1997 21:25:45 -0500
To: lwillner@dms-hp.ora.dnd.ca
From: "John A. O'Keefe IV" <jokeefe@triton.dmso.mil>
Subject: An Additional Web Address
Copies to: jokeefe@triton.dmso.mil, "Dr.Ir. M.P.I. Manders" <mande

Lisa

Forgot to add the following address to last night's list.

Coryphaeus Software (Visual Model and Terrain Database tools)
http://www.coryphaeus.com

Silicon Graphics http://www.sgi.com/

Open Graphics Language (Open GL)
http://www.sgi.com/Technology/openGL/opengl.html

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ANNEX Y
DOR(J&L) RN9812
July 1998

Sidestepping the 'Who Shot Who First' Dilemma

by Paul Seidenman

A new Army training range may prove useful in providing objective evaluations of force-on-force exercises. The system that makes it work could be of interest to the Corps for its ability to factor in the effects of combined arms.

While Marine Corps training has enjoyed a long tradition of excellence, a new training system at Ft. Polk, LA, offers the Marines and other ground forces vastly improved ground combat training. Along with significant enhancements in existing training methods, it provides increased realism, and does so for less cost.

Known as the Joint Readiness Training Center Instrumentation System, (JRTC-IS), the new system, which became operational in October, will completely modernize the current approach to training at Ft. Polk. Instead of relying solely on observers/controllers to visually monitor and "umpire" field training, the instrumented training system records every movement and weapons engagement by the participants (Figure 1). Replay of this data, augmented by audio and video, eliminates any controversy about the outcome of training engagements or the conduct of any specific portion of the training exercise.

Prior to JRTC-IS at Ft. Polk (and currently elsewhere), force-on-force training evaluation involved a degree of subjectivity (Figure 2). This was because the evaluation was done by an observer-controller team stationed in the field where the activity was taking place. Only the direct observations of the individual team members were recorded. In the Marine Corps, these observer teams are known as tactical exercise control groups (TECGs).

The TECG concept is impacted by more than what each member actually sees, according to LtCol Jerome McGovern, head of projects, Office of the Program Manager for Training Systems, Marine Corps Systems Command. He stated:

> When collecting the data during a training exercise, the TECG member is heavily influenced by his own training and background. This has an impact on what events he perceives as being important to evaluate and record. Because of this value judgment, some significant event could actually be overlooked.

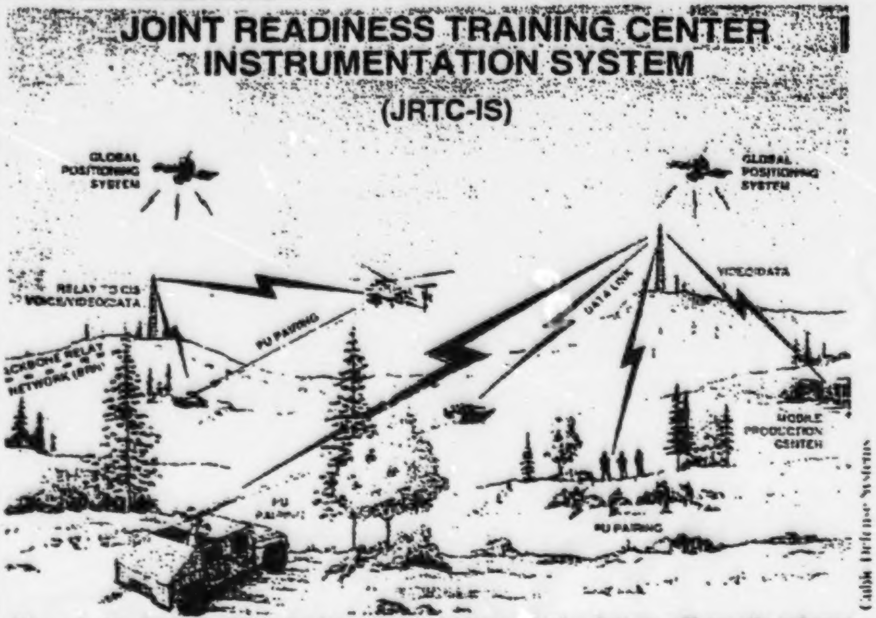
But the effectiveness of TECGs is also contingent upon other factors, such as how well the members of a specific TECG have been trained and how long they have worked together in the exercise data-collection process.

In addition, there are issues of cost, coupled with the disruption of the regular schedules of those pulled in to observe. TECGs vary in size and, depending upon where they are located, may be adequate for the evaluation of a training exercise typically conducted at their location. But, in the event of a large-scale exercise, it may be necessary to supplement these TECGs with groups from other locations. "Often, this means taking personnel away from other activities, which is very expensive in terms of time and manpower," said McGovern.

All of these factors mean that any after action review of a training exercise will have little or no truly objective data as a basis. Realizing the limitations of today's observer-controller teams, the Army opted to develop the JRTC-IS. The JRTC-IS was developed and installed by San Diego-based Cubic Defense Systems under a $63 million contract awarded in July 1993. The project is managed by the Army's Simulation Training and Instrumentation Command (Figure 3). The system gives the Ft. Polk training facility the most advanced technology of this type available to record key events and observations from the range. The collected data can be assembled, edited, and replayed for a truly objective afteraction review of light forces training. The current configuration will accommodate two battalion task forces with close air support, air transport, and special forces, going through rotations that average 20 days.

Field data is gathered by data communications interface (DCI) units that can be mounted on ground vehicles and helicopters, and also worn by personnel. Initially, 1,250 DCIs were deployed, with growth to 8,000 possible. The DCIs weigh only 3.1 pounds each and are designed to communicate the position of the vehicle or person—with either referred to as a "player"—along with the results of laser-based simulated weapons firing using Multiple Integrated Laser Engagement System (MILES) technology. The player position information will be determined using global positioning system satellites, and will be accurate to within 10 meters. The digital communications system has been shown to provide coverage over better than 99 percent of the heavily wooded training range, which covers an area of 20 by 50 kilometers.

The information gathered by the DCIs is relayed to, and processed at, the Core Instrumentation System (CIS), located in a central facility on the training range. The data transmission between the DCIs and CIS will be via an ultra high frequency radio link to four towers situated on the training


JOINT READINESS TRAINING CENTER
INSTRUMENTATION SYSTEM
(JRTC-IS)
GLOBAL POSITIONING SYSTEM
GLOBAL POSITIONING SYSTEM
RELAY TO CIS VOICE/VIDEODATA
VIDEODATA
BACKBONE RELAY NETWORK (BRN)
PU PAIRING
DATA LINK
MOBILE PRODUCTION CENTER
PU PAIRING
PU PAIRING

Cubic Defense Systems

Figure 1. The Joint Readiness Training Center Instrumentation System will greatly enhance ground combat training.

range. From those towers, the data will then be sent directly to the CIS through buried fiber optic cables.

"The CIS is really the heart of the JRTC-IS," said Ed Zbik, a senior program manager with the developing contractor. "The CIS building will house 85 workstations where analysts will be positioned to supervise the collection and processing of all the data."

The system's software allows an analyst to display a computer-generated digital map. The map will represent the entire training range, indicating the position of troops and vehicles through digitally generated symbols indicating both friendly and opposing forces. Zbik said of the system's capabilities:

> In addition, the analyst can selectively monitor the entire exercise, or zoom in to see the smallest component of the training scenario in progress. In fact, using raw digital terrain data the software can construct a map to shov details of a specific area for the analyst, such as the movements of th players and terrain characteristics, a well as the presence of such contrc measures as barbed wire installation or minefields.

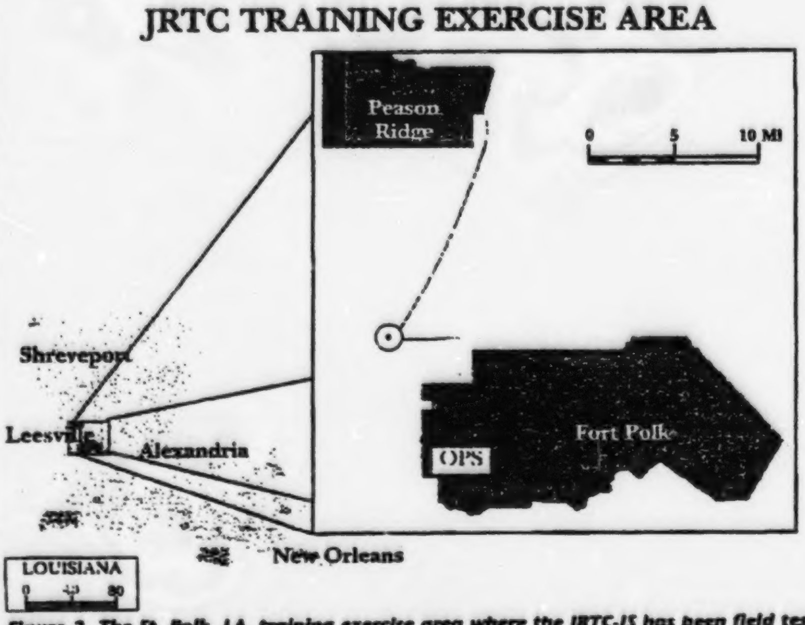
According to Zbik, the analyst ca even configure the system to war him when a selectable battle conditio has occurred, such as a player enterin a particular area, two units gettin within a certain distance of each other, or any of numerous other situations.

Not only will the CIS-based sof ware record all of the training exercis events, including simulated weapon firing and movement of troops and v hicles, but it will give the analysts th ability to accumulate a database of si nificant events regarding the actior of the players. With the click of mouse, any actions can be tagged wit an electronic time and date stamp fo closer evaluation during the aftera tion review. A tagged event can be i the form of recorded voice, video, c the freeze of a specific display on th digital map.

Additionally, the database recorc information about personnel an equipment battle damage, indire fire missions (including nucle chemical, and biological), unit stru ture, usage and inventory of comb supplies, medical evacuation data, sp cial forces control measures, and sc tie data for air assets. And, becau events can be viewed as they are ha pening, the analysts and the comma ders will be able to determine hc well the exercise is being played out conformance with the commande intent. Zbik added:

> The commanders, themselves, c monitor the training exercise fr the CIS to make sure that the pre fined training scenarios are being f lowed as closely as possible. This w allow the commander to modify t scenario if training objectives are r being met.

The afteraction review is cons ered to be the primary objective of t instrumentation system. To that e the contractor designed three fix and two mobile theaters that use multimedia/multiscreen format presentation of text, graphics, voi video, and digitally generated replay player movements on user-selecta


JRTC TRAINING EXERCISE AREA
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Leesville
Alexandria
OPS
Fort Polk
New Orleans
LOUISIANA
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Figure 2. The Ft. Polk, LA, training exercise area where the JRTC-IS has been field tested.

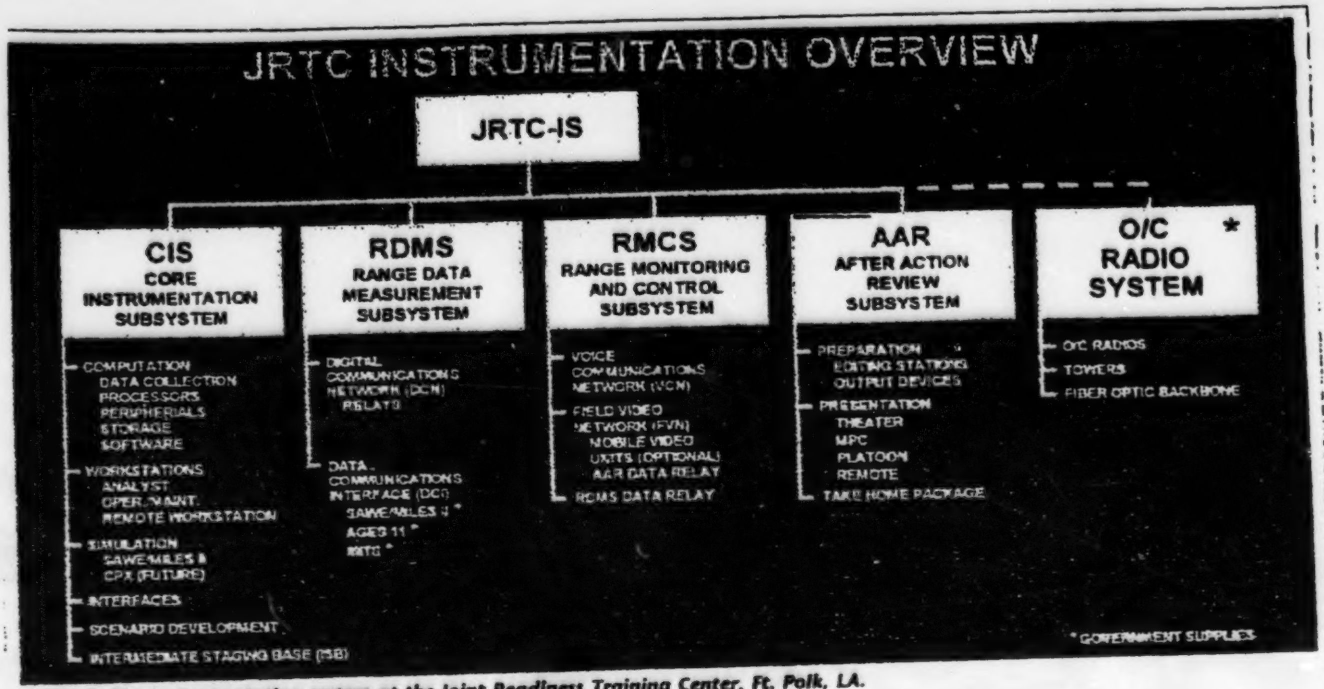
JRTC INSTRUMENTATION OVERVIEW
JRTC-IS
CIS
CORE INSTRUMENTATION SUBSYSTEM
COMPUTATION
DATA COLLECTION
PROCESSORS
PERIPHERIALS
STORAGE
SOFTWARE
WORKSTATIONS
ANALYST
OPER./MAINT.
REMOTE WORKSTATION
SIMULATION
SAWE/MILES II
CPX (FUTURE)
INTERFACES
SCENARIO DEVELOPMENT
INTERMEDIATE STAGING BASE (ISB)
RDMS
RANGE DATA MEASUREMENT SUBSYSTEM
DIGITAL COMMUNICATIONS NETWORK (DCN)
RELAYS
DATA COMMUNICATIONS INTERFACE (DCI)
SAWE/MILES II *
AGES II *
MTG *
RMCS
RANGE MONITORING AND CONTROL SUBSYSTEM
VOICE COMMUNICATIONS NETWORK (VCN)
FIELD VIDEO NETWORK (FVN)
MOBILE VIDEO UNITS (OPTIONAL)
AAR DATA RELAY
RDMS DATA RELAY
AAR
AFTER ACTION REVIEW SUBSYSTEM
PREPARATION
EDITING STATIONS
OUTPUT DEVICES
PRESENTATION
THEATER
MPC
PLATOON
REMOTE
TAKE HOME PACKAGE
O/C RADIO SYSTEM *
O/C RADIOS
TOWERS
FIBER OPTIC BACKBONE
* GOVERNMENT SUPPLIES

Figure 3. The instrumentation system at the Joint Readiness Training Center, Ft. Polk, LA.

maps. The fixed theaters are each equipped with 75 seats, while the two mobile theaters can seat up to 25 each.

The information collected during the training exercise, however, is also expected to go beyond the afteraction review. The Center for Army Lessons Learned will analyze exercise data and potentially recommend changes in training doctrine based on JRTC-IS input. As new weapons come into the inventory, the system also will be able to determine how well they have been deployed during the exercise. In fact, the modular design of the JRTC-IS software allows it to be easily upgraded to accommodate new weapons and capabilities—either simulated or real. Among the upgrades under review for JRTC-IS is the new-generation MILES, dubbed MILES 2000, currently in the preproduction phase at Cubic Defense Systems.

Because the JRTC-IS will be available to all Services, the potential is there for Marine Corps training to benefit from the use of this instrumented training range. According to LtCol McGovern, the Corps should take that opportunity. He stated:

> It would enable us to engage in a training exercise that eliminates almost all the human factors with respect to data collection. We could capture far more raw data, objectively, than can be gathered by field observers taking hand-written notes.

McGovern added that the instrumented training range will allow all combat arms to be brought into the training exercise, including those that are normally excluded, because there was no way to effectively evaluate them or score their performance. He explained:

> A training exercise might involve a company going through a corridor that is subject to artillery fire. At this time, the controller must manually observe the simulated fire, and basically act as a judge to determine if any targets were hit—specifically which ones—in order to score the number of casualties. With a computerized scoring system, the commanders will now receive an exact report of everything that happened—including action from artillery, events taking place in minefields, and the effect of close air support—even nuclear, biological, and chemical warfare.

For the Marines, McGovern said, one of the most important advantages of the JRTC-IS is the system's adaptability to the needs of the various branches of the Armed Services.

> The software is now based on Army specs known as the Mission Essential Task List (METL)—a tightly defined set of steps that the commander must do to carry out the training. In the Marine Corps, the steps are not as tightly defined, so the Marines could take advantage of the JRTC-IS almost as is. The only issue would be the availability of the range itself.

McGovern added that the JRTC-IS may be an important step in an ongoing goal of the military to expand training exercises to various locations, yet coordinate them as if they were on the same training range. He concluded:

> In the next 10 years, the military will be moving to a situation where a single training exercise can be carried out on multiple ranges. Something like JRTC-IS could be included with an air combat training range. A lot of this will involve joint training, and the big advantage of this will be that, thanks to the technology, there will be no need to move units and equipment to one specific location. That is the kind of a role that an instrumented training range could play in the next decade.

US MC

>Mr. Seidenman has worked as an independent journalist for 16 years and has experience covering aviation and military stories. He currently is based in San Francisco. An earlier article on the JRTC appeared in MCG, Feb96.

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SPECIFICATION, HARMONIZATION, AND LINKAGE OF TEST PARAMETERS

Edward D. Jones

This article addresses how to best specify "what to test" parameters. It will also clarify the latest DoD 5000 series guidance as approved by the Secretary of Defense on 9 March 1996 on the establishment and maintenance of parameter linkage and harmonization among the key acquisition documents.

While the newly revised Department of Defense (DoD) 5000 series does make significant progress implementing acquisition reform, confusion will likely continue to exist in the test and evaluation arena as to how to best specify test parameters for an acquisition program (Figure 1).

A proliferation of "what to test" terminology remains among the various parts of the DoD 5000 series. A formal glossary that will perhaps define these terms is still being compiled. On pages 149–151 is a partial listing of "what to test" terminology used in this article. For purposes of brevity, acronyms may not be defined except in this terminology list. Braces and brackets indicate an acquisition document where the term is used.

"WHAT TO TEST"

Some of the "what to test" terms may refer to the same required capabilities and associated thresholds and objectives. Often, they do not. Inherent relationships or linkages are not specified for most of these terms. Figure 2 summarizes the DoD 5000 series mandated sources for the most important "what to test" parameters.

The proper usage of "what to test" terms in reports and in discussions with oversight agencies can be important. Some of the terms have their origin in Title 10 law. For example, effectiveness and suitability are addressed in legislation that mandates how we will conduct dedicated initial operational test and evaluation. The test manager and program manager must

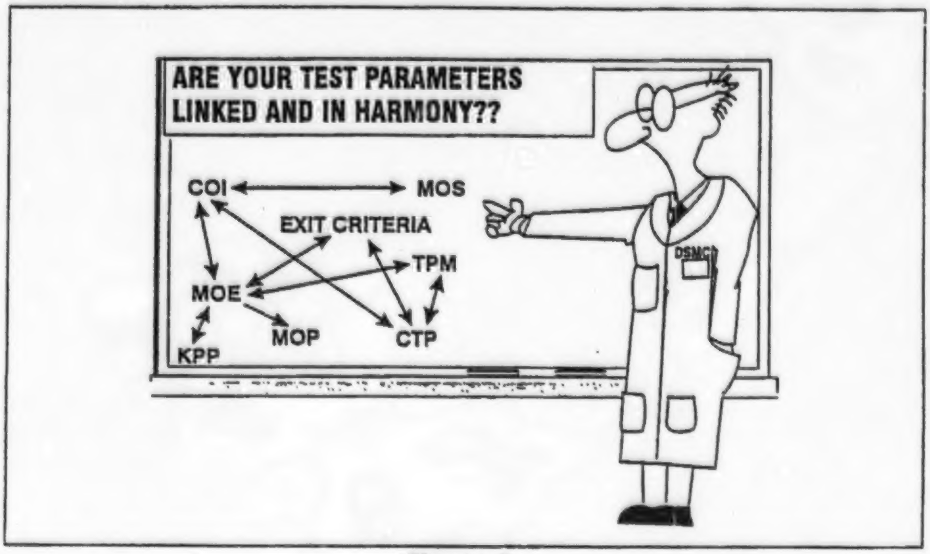


Figure 1.

take care when discussing what is actually being tested or evaluated. For example, assume a test for an ACAT ID acquisition program indicates that a threshold is not achieved for a TPM that is also a specified exit criteria.

Who has oversight for these test parameters? The contractor and government technical managers have oversight over TPMs. Unless the TPM is also designated as a critical technical parameter, it will not be listed in the TEMP and will normally not be subjected to Office of the Secretary of Defense (OSD) oversight at the overarching Integrated Product Team (IPT) level. However, all exit criteria by definition are under the direct oversight of the milestone decision authority (MDA). This means that failure to meet the threshold for an exit criteria could prevent the acquisition from proceeding into the next acquisition phase. This could be an emotional event! Compare this with failing to meet a threshold of TPM that is not a CTP or not specified to be an exit criteria. The contractor and government technical manager would take appropriate actions to solve the problem under the oversight of the program manger and the appropriate working level IPT. This article will recommend a method to specify test parameters that simplifies the "what to test" terminology.

LTC Edward D. Jones presently serves as a professor of engineering management at the Defense Systems Management College, Fort Belvoir, VA. Jones received his B.S. degree from the U.S. Military Academy in 1974 and a M.S. degree in chemical engineering from Vanderbilt University in 1987.

"WHAT TO TEST" TERMINOLOGY

Compatibility, Interoperability, and Integration (CII) Issues. {Appendix III, DoD REGULATION 5000.2-R} Defined to be critical operational issues that address compatibility, interoperability or integration issues. [Test and Evaluation Master Plan or TEMP]

Critical Operational Issue (COI). {Appendix III, DoD REGULATION 5000.2-R} A question that must be answered in order to properly evaluate operational effectiveness and operational suitability for a system. [TEMP]

Critical Operational Effectiveness and Suitability Parameters and Constraints. {Appendix III, DoD REGULATION 5000.2-R} Parameters and constraints as specified in the ORD that address manpower, personnel, training, software, computer resources, transportation (lift), compatibility, interoperability, and integration, etc. These parameters and constraints are included in the listing of measures of effectiveness and suitability in Part I of the TEMP. [TEMP, ORD]

Critical Technical Parameter (CTP). {Appendix III, DoD REGULATION 5000.2-R} Not defined. They are to be derived from the ORD, critical system characteristics, and technical performance measurements and should include the parameters in the acquisition program baseline. [TEMP]

Exit Criteria. {Paragraph 3.2.3, DoD REGULATION 5000.2-R} Exit criteria are some level of demonstrated performance (e.g., a level of engine thrust), the accomplishment of some process at some level of efficiency (e.g., manufacturing yield) or successful accomplishment of some event (e.g., first flight), or some other criterion (e.g., establishment of a training program or inclusion of a particular clause in the follow-on contract) that indicates that aspect of the program is progressing satisfactorily. [ADM]

Indicators. {Paragraph 3.4.3, DoD REGULATION 5000.2-R} One or more measurements that provide insight when compared with test-established thresholds. [Not mandated for usage in any key acquisition document; however, frequently used in test reports and program assessments.]

Key Performance Parameter (KPP). {Paragraph 2.3, DoD REGULATION 5000.2-R} A capability or characteristic that is so significant that failure to meet the threshold can be cause for the concept of system selection to be reevaluated or the program to be reassessed or terminated. [ORD, TEMP, Aquisition Program Baseline or APB]

Measures. {Used through out DoD 5000 series} Not defined. As defined in IEEE 1278.3, a qualitative or quantitative attribute used to ascertain or appraise by comparing to a standard. [TEMP, Analysis of Alternatives]

Measures of Effectiveness and Suitability (MOEs/MOSs). {Appendix III, DoD REGULATION 5000.2-R and in other parts} The following definition is inferred from a discussion of measures of effectiveness and suitability in Appendix III. The operational performance (effectiveness and suitability) parameters that specify capabilities, characteristics, and constraints as identified in the ORD. Each measure of effectiveness and suitability is to have a threshold and an objective. [TEMP, Analysis of Alternatives, ORD]

"WHAT TO TEST" TERMINOLOGY (CONTINUED)

Measure of Performance (MOP). {Paragraph 3.4.1; Appendix III. DoD REGULATION 5000.2-R} Not defined. A commonly accepted definition is: a measure, such as weight and speed, that relates to a measure of effectiveness such that the effect of a change in the measure of performance can be related to a change in the measure of effectiveness. {1992 OUSD (A&T) memorandum: subject: Implementation Guidelines for Relating Cost and Operational Effectiveness Analysis (COEA) Measure of Effectiveness to test and evaluation.} [TEMP. ORD Analysis of Alternatives]

Metrics. {Paragraph 4.3, DoD REGULATION 5000.2-R} Not defined. As defined in *Webster's Dictionary*, metrics is the extent or degree to which a product possesses and exhibits a quality, or property, or an attribute. This term is more commonly used when addressing software testing and evaluation. [TEMP]

Minimum Acceptable Requirements. {Paragraph 2.3, DoD REGULATION 5000.2-R} While not specifically defined, it can be logically inferred that minimum acceptable requirements are the minimum capabilities and characteristics that a system must possess in order to successfully accomplish all mission essential tasks. [ORD]

Objective. {Paragraph 2.3.2, DoD REGULATION 5000.2-R} The objective value is that *desired* by the user and which the PM is contracting for or otherwise attempting to obtain. The objective value could represent an operationally meaningful, time critical, and cost effective increment above the threshold for each program parameter. [TEMP, ORD, APB]

Operational Performance Parameters. {Appendix II, DoD REGULATION 5000.2-R} These are system level performance capabilities such as range, probability of kill, platform survivability, operational availability, etc. Each parameter should have an objective and threshold. [ORD]

Other Systems Characteristics. {Appendix II. DoD REGULATION 5000.2-R} A special category of characteristics that tend to be design, cost, and risk drivers. Examples include electronic counter-countermeasures (ECCM) and Wartime Reserve Modes (WARM) requirements and others as listed in Appendix II of DoD REGULATION 5000.2-R. [ORD]

Parameter. {DoD REGULATION 5000.2-R} This term is liberally used throughout the DoD 5000 series. It is not defined. As defined in the *American Heritage Dictionary*, a parameter is a variable or an arbitrary constant appearing in a mathematical expression, each value of which restricts or determines the specific form of the expression. Current usage in the DoD 5000 series and in other current literature used by the test community have broadened the definition to be equivalent to any test variable, whether formally part of a mathematical equation or not. Probability of hit is one example that does meet the technical definition of a parameter. [TEMP, ORD, APB]

Required Capabilities. {Used throughout DoD REGULATION 5000.2-R} Not defined. A commonly accepted definition is: system performance or characteristics that a system must possess in order to accomplish mission essential tasks. [ORD, TEMP, APB, Analysis of alternatives]

"WHAT TO TEST" TERMINOLOGY (CONTINUED)

Technical Performance Measurement (TPM). {Appendix III, DoD REGULATION 5000.2-R} Not defined. A common definition that is accepted in systems engineering follows: A product design assessment, which estimates through engineering analysis & tests, values of essential performance parameters of the current design of a work breakdown structure product element. [SEMP, contract]

Thresholds. {Paragraph 2.3.2, DoD REGULATION 5000.2-R} These are the minimum acceptable values which, in the user's judgment, are necessary to satisfy the need. If threshold values are not achieved, program performance is seriously degraded, the program may be too costly, or the program may no longer be timely. The spread between objective and threshold values shall be individually set for each program based on the characteristics of the program (e.g., maturity, risk, etc.). [ORD, TEMP, APB]

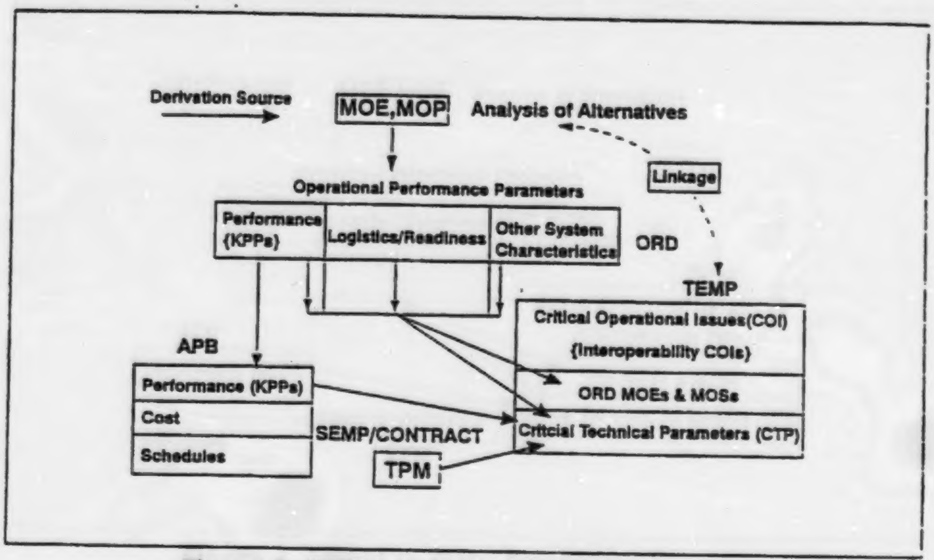

Derivation Source
MOE,MOP
Analysis of Alternatives
Linkage
Operational Performance Parameters
Performance (KPPs)
Logistics/Readiness
Other System Characteristics
ORD
TEMP
Critical Operational Issues(COI)
(Interoperability COIs)
ORD MOEs & MOSs
Criticial Technical Parameters (CTP)
APB
Performance (KPPs)
Cost
Schedules
SEMP/CONTRACT
TPM

Figure 2. "What to Test" Parameter Sources

IMPLEMENTATION POLICY FOR PERFORMANCE PARAMETER SPECIFICATION

The TEMP lists the "what to test" parameters, outlines the strategy to conduct the testing, provides a summary of required test resources, and assigns responsibilities. *Note that the tester limits the "what to test" terminology to: measures of effectiveness, measures of suitability, measures of performance, critical technical parameters, critical operational issues, critical system characteristics and compatibility, inter-operability, and integration (CII) issues.* Terms such as software metrics, operational performance parameters, system constraints, minimum required capability and required capabilities are incorporated into the TEMP as one of the preceding "what to test" parameters, measures or issues! How do all the "what to test" parameters, measures, and issues that are commonly used by the tester tie together? Figure 3 illustrates the relationships between the "what to test" parameters during operational testing.

A critical operational issue (COI) addresses a key operational effectiveness or operational suitability issue that must be examined in operational test and evaluation to determine the system's capability to perform its mission. The COI is stated as a question and should address top system level mission essential tasks. MOEs provide (quantitative whenever practical) criteria that can be used to judge whether a system can effectively provide the required capabilities as stated in the ORD. Each MOE should provide information that is to be used to answer one or more effectiveness COIs. When a COI addresses suitability, the measure of effectiveness is replaced by the MOS. The MOP is a (quantitative when practical) criteria for a lower level of performance that is used to support the determination

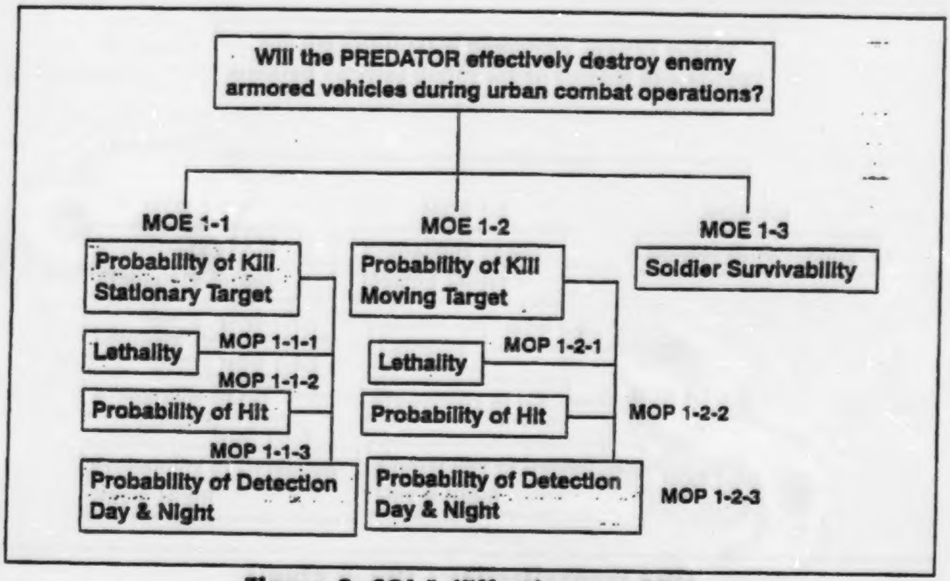

Will the PREDATOR effectively destroy enemy armored vehicles during urban combat operations?
MOE 1-1
Probability of Kill Stationary Target
MOE 1-2
Probability of Kill Moving Target
MOE 1-3
Soldier Survivability
Lethality
MOP 1-1-1
MOP 1-1-2
Probability of Hit
MOP 1-1-3
Probability of Detection Day & Night
Lethality
MOP 1-2-1
Probability of Hit
MOP 1-2-2
Probability of Detection Day & Night
MOP 1-2-3

Figure 3. COI 1 {Effectiveness COI}

or assessment of one or more MOEs or MOSs. MOEs, MOSs, and MOPs are normally extracted directly from the ORD. In some cases, they must be derived from the ORD. On an exceptional basis, MOEs, MOSs, and MOPs can be recommended for testing by the Director of Operational Test and Evaluation (DOT&E) or by the appropriate component Operational Test Agency (OTA). This might occur when the OTA or DOT&E determine that the required capabilities and characteristics are not adequate for operational testing. MOEs, MOSs, and MOPs that are not extracted or derived from the ORD must be approved through the IPT process prior to being used for determination of effectiveness and suitability in an independent evaluation report such as the beyond low rate initial production report. The user will establish thresholds and objectives for any DOT&E or OTA recommended MOEs, MOSs, and MOPs.

COIs and operational performance parameters are most appropriately tested in an operational environment. An operational environment is the same or closely approximated environment that the system will be used in when issued to the user. Testing in a controlled environment that may significantly deviate from operational conditions or testing that is limited to a specific set of operational conditions is called developmental testing. Another "what to test" parameter listed in the TEMP is CTP. While MOEs and MOSs are specified to support the determination of effectiveness and suitability in an operational environment, the CTP is specified to measure progress in the hardware and software development to support the final product to be used in a fully operational environment. Developmental testing is normally the more appropriate type of testing for CTPs. DoD guidance is that the CTP may be derived from the ORD and critical system characteristics or chosen from the list of technical performance measurements as specified in the SEMP or extracted directly from the contract. System level TPMs that measure performance essential to accomplishment of mission essential tasks should be specified to be CTPs. A possible exception to this guideline is an extremely high risk component level TPM that significantly impacts one or more system level TPMs.

In the past, specification of CTPs versus minimum acceptable operational performance parameters (MAOPRs) has been problematic. For many programs, the CTP and MAOPR lists duplicated each other. The problem arises because the ORD is an approved source for both the MAOPR and the CTP. This issue remains in the revised DoD 5000 series. The MAOPR has been replaced with MOEs and MOSs. When should MOEs and MOSs also be CTPs? This article recommends an approach to CTP specification that will minimize duplication of CTPs and operational performance parameters (MOEs, MOS, MOPs) and, more important, clearly establish a key difference between operational performance parameters and CTPs.

This process is to simply limit the specification of CTPs to performance that is contractually specified. While this recommendation is not specifically supported by guidance in the DoD 5000 series, it is well within the guidance for parameter specification. For most acquisition programs, specified performance in a contract is best tested in a controlled environment during developmental testing. TPMs are by definition contractually specified and are always a valid source for CTPs. When operational performance parameters are specified in the contract, then they should normally be specified as CTPs. This recommendation will minimize duplication between operational performance parameters and CTPs. The specification process is based on the premise that operational performance parameters are best tested during operational testing while CTPs and TPMs are more appropriately tested during developmental testing. This process recognizes that some duplication will occur between CTPs and operational performance parameters and does not restrict the testing of each type of test parameter in either an operational, developmental, or hybrid mode of testing.

..itical: Technical Parameter:

Technical: Performance Measurements

Now let us address the concepts of parameter linkage and harmony. The concept of parameter linkage and harmonization was first introduced in a March 1992 memorandum that was signed by the Under Secretary of Defense for Acquisition, the Assistant Secretary of Defense (Program Analysis and Evaluation), and the Director, Operational Test and Evaluation. This memorandum mandated that the TEMP should document how measures of effectiveness and measures of performance from the COEA will be addressed in testing and evaluation. In the COEA, measures of effectiveness were to be defined to measure operational capabilities in terms of engagement or battle outcomes for weapon systems. Measures of performance such as speed and weight were to be specified to relate to the MOE such that the effect of a change in the MOP can be related to a change in the MOE. It further mandated that the MOEs, MOPs, and criteria in the ORD, the COEA, the TEMP, and the APB should be consistent. These mandates were incorporated into Part III of the revised DoDI 5000.2 as quoted below:

> Linkage shall exist among the various MOEs and MOPs used in the analysis of alternatives or ORD, and test and evaluation; in particular, the MOEs, MOPs, and criteria in the ORD, the analysis of alternatives, the TEMP and the APB shall be consistent.

and

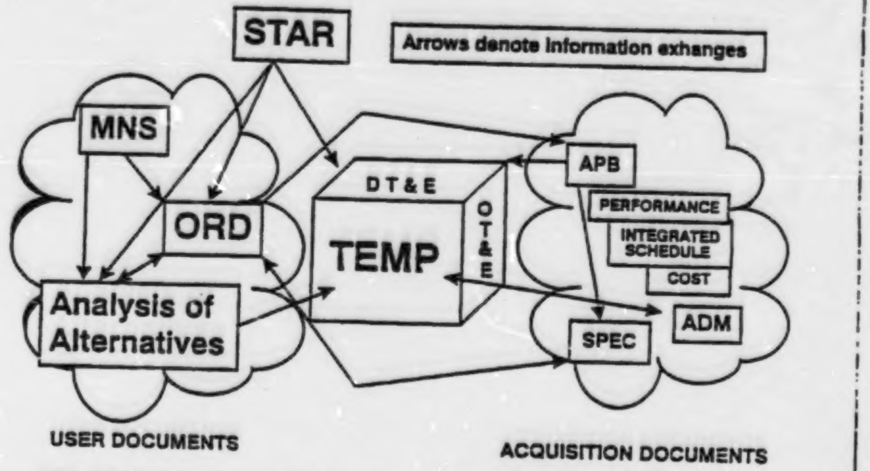
> Both developmental and operational testers shall be involved early to ensure that the test program for the most promising alternative can support the acquisition strategy and to ensure the harmonization of objectives, thresholds, and measures of effectiveness (MOEs) in the ORD and TEMP.

In the past, linkage was described as the process of associating (or linking) measures of effectiveness and measures of performance that were used as inputs in models and in analytic studies with actual test data and evaluated results that were based on actual test data. The purpose of this association was to ensure that realistic inputs were used in models and analytic studies. Harmonization was the process of ensuring consistency among the all the various measures and parameters to include associated thresholds and objectives. The translation of past guidance into the new DoD 5000 series has lost some of the precision associated with defining the linkage and harmonization process. Harmonization and linkage have adopted the same meaning, for practical purposes. That meaning is consistency. This consistency has three key ingredients:

- agreement on thresholds and objectives for the same measures and parameters,
- compatibility of measures and parameters, and
- realistic (consistent with test data) inputs into studies and models.

The concept of harmonization and linkage should be considered to mean the process of establishing and maintaining consistency among all the measures, parameters, and inputs to models and analytic studies. This consistency must extend to all the key acquisition documents (Figure 4).

Harmonization and linkage are most easily discussed practical examples; three follow. First, during an analysis of alternatives, assume that the threshold speed (a measure of performance) for an armored vehicle was established to be 80 km/h on improved roads. This threshold speed might be a significant input into the models and studies that recommended that tank A be the preferred alternative. Then assume that during developmental testing of a prototype tank A, it is discovered that this type of tank will not exceed 73 km/h on improved roads. It is also assumed that the engineering change proposals to increase the speed to 80 km/h is cost and schedule prohibitive. For this example, the concept of linkage and harmonization requires that actual test data for tank A on speed on improved roads be compared with inputs that were used in the models and studies that were used in the analysis of alternatives. Where necessary, previous



NOTE: MNS-Mission Need Statement; STAR-System Threat Assessment Report; SPEC-Specifications.

Figure 4. Parameter Consistency (Harmonization And Linkage)

inputs (measures of effectiveness and performance, system constraints, etc.) must be changed to reflect the more realistic inputs that are based on actual test data. For our example, we would have to establish whether the lower threshold speed of 73 km/h versus the earlier threshold of 80 km/h has a significant impact on the selection of the preferred alternative.

For a second example, assume the threshold for mean time between failure (MTBF) for a radio system to be 1250 h. The MTBF threshold would be listed in the TEMP, ORD and possibly in other key acquisition documents such as the APB. Assume the mean time to repair (MTTR) to be specified as 30 min at all levels of maintenance. In the analysis of alternatives, assume the system to have been required to have not more than 45 min of not available time for repairs on an annual basis. In the ORD or other user document, assume the system to have the requirement to be placed into operation for 2500 h on an annual basis. Now, the question to answer is: "Are these required capabilities and associated parameters in harmony (consistent)?" In this case, the required performance parameters are not in harmony. Simple math will reveal a discrepancy. During one year, the system should fail on average twice. Two times 30 min indicates that, on average, 60 min of downtime should be expected for this system. This conclusion indicates that the system should be expected to have more than 45 min of not available time on an annual basis. The "what to test" parameters among the TEMP, ORD, and analysis of alternatives are not consistent (harmonized). This problem can be fixed by decreasing the mean time between failure or by increasing the threshold for the not available time from repairs. The preceding example illustrates the compatibility aspect of consistency.

The final example illustrates the simplest aspect of consistency. That is simple agreement of thresholds and objectives for the same operational performance parameter or other "what to test" parameter. Assume that the TEMP lists a MOP that specifies the threshold for the probability of hit for a shoulder-launched missile to be 50% for stationary targets at 600 m. In the APB, assume the threshold for probability of hit to be 60% for the same conditions. To establish consistency, the probability of hit thresholds in the TEMP and APB must be the same for stationary targets at 600 m.

Now that we have discussed the "what to test" terminology and the concepts of linkage and harmonization, it is how time to establish an orderly and efficient process to effectively specify "what to test" parameters and to establish consistency (harmony and linkage) among measures, parameters, and inputs for models and analytic studies (Figure 5).

TEST PARAMETER SELECTION, LINKAGE, AND HARMONIZATION

Step one. Establish a working-level IPT (analysis of alternatives/requirements/what to test) that:

- specifies the required capabilities and operational performance parameters with associated thresholds and objectives in the initial ORD and the preliminary TEMP,
- inputs the required capabilities and associated operational performance parameters for each alternative considered in an analysis of alternatives,
- recommends performance parameters to be used in the draft APB,

STEP ONE:	ESTABLISH IPT.
STEP TWO:	DRAFT ORD.
STEP THREE:	SPECIFY COI AND CII.
STEP FOUR:	SPECIFY MOEs AND MOSs
STEP FIVE:	INPUT TO APB.
STEP SIX:	SPECIFY CTPs.
STEP SEVEN:	PREPARE PARAMETER DENDRITIC.
STEP EIGHT:	PREPARE CONSISTENCY MATRIX.

Figure 5. Eight-Step Process to Specify "What to Test" Parameters

- specifies the CTPs for the draft TEMP. and
- establishes and maintains consistency (linkage and harmonization) for all "what to test" parameters and criteria among all key acquisition documents. (APB, TEMP. Analysis of Alternatives. ORD. SEMP [if applicable]).

IPT membership should include representatives from the (1) user, (2) material developer, (3) operational tester , (4) developmental tester, (5) agency tasked to conduct analysis of alternatives, (6) logistics support agency, and others as appropriate. This IPT could be assigned the task of actually conducting the analysis of alternatives or be placed in support of another IPT that will perform the analysis of alternatives. In theory (in practice all the key acquisition documents are often prepared simultaneously), the analysis of alternatives is normally the first document to be drafted. The operational performance parameters that are used in the analysis of alternatives should not be system specific but should be applicable for all alternatives. The tester has the important role in this process of providing input as to how to properly state required capabilities in terms that can be tested. The user, as a member of the IPT, should take the lead in preparing a draft ORD with broadly defined system characteristics for each alternative under consideration. These draft ORDs will greatly aide in the analysis by providing a basis for numerical inputs for MOEs, MOSs, and MOPs that are used in the analysis. Step one has the following goals:

- Identify the performance and cost advantages and disadvantages between proposed systems over the existing system and/or a modified system.
- Broadly define the system characteristics needed in the new system.
- Select the preferred alternative to carry into Phase I of the acquisition cycle.

Step two. The IPT, with the user taking the lead, should then formalize the draft ORD (see step one) for the preferred alternative. In paragraph four of the ORD, list the required capabilities as operational performance parameters. The format for the ORD is prescribed in Appendix II of DoD REGULATION 5000.2-R. Results from the analysis of alternatives should be used to better define those system characteristics that are important in ensuring that the system meets the user's needs. The operational performance parameters in paragraph four of the ORD should be stated in a manner that facilitates their translation into MOEs, MOSs, and MOPs for listing in the TEMP. Each operational performance parameter should be readily identifiable and have a clearly stated threshold and objective. Examples of good and bad operational performance parameters follow:

Good: The KILLER must have a probability of kill for stationary targets that meets or exceeds 90% in the range band of 20– to 250 m during day operations in all types of weather and terrain. The desired probability of kill for this type of target is 95%.

Bad: The KILLER must have a probability of kill for moving targets that meets or exceeds that of the legacy system.

Comments: The good operational performance parameter clearly indicates that the test parameter is probability of kill. It clearly states the threshold and objective. It also provides an adequate amount of information to establish the environment. The bad example fails to clearly state the thresholds, objectives, and environmental conditions.

Key Performance Parameters

A preliminary choice of KPPs should be made at this time. They will be formally approved at component level and by the JROC.

Critical Operational Issues

Compatibility Interoperability & Integration Issues

Step three. Specify the COIs and the CIIs. As part of the IPT process, the user and the operational tester should assume the lead in the specification of the COIs and CIIs. The COIs should address the top system level mission essential tasks. A good source for the identification of COIs are paragraph one and the introductory statements for paragraph four in the ORD. For example, the ORD states that a helicopter will conduct armed and unarmed reconnaissance and security operations in combat. An appropriate COI that addressed this mission essential task might be: "Can helicopter A conduct armed and unarmed reconnaissance and security operations in combat?" COIs are questions that when answered support a determination of system effectiveness and suitability. The number of COIs to adequately address effectiveness and suitability normally range from 3 to 10. The absolute minimum is 2, one for effectiveness and one for suitability.

The determining factor as to how many COIs are needed is the number of mission essential tasks. Carefully specified COIs have the potential to address more than one mission essential tasks. Each COI requires a sufficient number of MOEs or MOSs to adequately determine an answer. An excessive number of COIs tends to increase the total number of test data elements that must be collected during operational testing and should be avoided whenever possible. The CII is a special type of COI that addresses compatibility, interoperability, or integration issues. A good source for the specification of CIIs is the other system characteristics listed in paragraphs 5f and 5h in the ORD. It is possible to specify one COI that adequately addresses all the compatibility, interoperability, and integration issues. For example, "Is the KILLER compatible and effectively integrated with other systems on the battlefield? Note that this is a standalone system and has no interoperability issues."

Step four. As identified in the ORD, specify system specific MOEs and MOSs and supporting MOPs as required. List the thresholds and objectives for these operational performance parameters in matrix format (recommend by the author but not mandated by DoD REGULATION 5000.2-R) in Part I of the TEMP. The ORD also suggests that those operational performance parameters that support the determination of other parameters be designated to be MOPs. A numbering scheme should be used to reflect which parameters are MOEs and MOSs and which parameters are MOPs. For example, MOP 1-2-3 indicates that this operational performance parameter is MOP 3 and that it supports the determination of MOE 2 or MOS 2 which supports COI 1. If COI 1 is an effectiveness COI then MOE 2 is appropriate.

COI	MOE/MOST/MOP/CTP: (Parameter): Threshold/Objective	Analysis of Alternatives: Threshold/Objective	APB Parameter: Threshold/Objective
COI 1: Kill Enemy Armor?	MOE 1-1 (Probability of Kill: .9/.95	Probabilty of Kill: .9/.95	Probability of Kill: .9/.95
	MOE 1-2 (Survivability): Yes or No	Survivability	
	MOP 1-1-1 (Probability of Hit—Moving): .5/.8	Probability of Hit—Moving: .5/.8	Probability of Hit—Moving: .5/.8
	MOP 1-1-2 (Probability of Hit—Stationary): .8/.9	Probability of Hit—Stationary: .8/.9	Probability of Hit—Stationary: .8/.9
	MOP 1-2-1 (Soft Launch): Yes or No	Soft-Launch Capability	Soft Launch Capability
	MOE 1-3/CTP 3 (Weight): 20 lbs/16 lbs	Weight: 20 lbs/16 lbs	Weight: 20 lbs/16lbs
COI 2-Supportable in Combat?	MOS 2-1 (Reliability) .9/.9	Reliability: .9/.9	Reliability: .9/.9
	MOS 2-2 (Transportable): Yes or No	Transportable: Yes or No	
	MOS 2-3 (Maintenance Concept): No Maintenance Required	Maintenance Concept	
Etc.	Etc.	Etc.	Etc.

Figure 6. Consistency (Harmonization–Linkage) Matrix

Step five. If not the same IPT, this IPT should provide a recommended list of performance parameters to the IPT that is drafting the APB. Those parameters should be limited to those parameters designated as key performance parameters in the ORD. The MDA has the latitude to add other performance parameters to this list. Performance parameters that are cost drivers are candidates for inclusion as a performance parameter in the APB. The analysis of alternatives should be an excellent source document for the appropriate IPT to use to identify performance parameters that are cost drivers. For example, miles per gallon for the M1A2 tank is cost driver for life cycle costs for the tank.

Critical - Technical Parameters

Step six. Specify the CTPs. In the past CTPs and MAOPRs (now called operational performance parameters) were considered to be interchangeable. But CTPs should be considered to be distinctly different from operational performance parameters. Operational performance parameters are more appropriately tested in an operational (uncontrolled) environment; CTPs are more appropriately tested in a developmental (controlled) environment. As part of the IPT process, the material developer representatives supported by the contractor and the government technical test manager should take the lead in CTP specification. While the ORD is specifically stated to be a source for CTPs, they should be limited to system level performance that is specified in the contract. Technical performance measurements are normally used by the contractor and the government system engineers to manage the engineering development of a system. The most significant system level technical performance parameters are the best candidates for selection as CTPs. Not all system level TPMs should be designated to be CTPs—only those can be directly linked to supporting a mission-essential task from the ORD. For example, a system-level TPM might be miles per gallon under tightly controlled driving conditions. This TPM directly supports the achievement of a mission-essential task for tank mobility without refueling for some specified distance. Therefore this TPM is an appropriate CTP. Appendix III of DoD REGULATION 5000.2-R states that CTPs should include parameters from the APB. I recommend that this guidance be implemented as follows:

echnical Performance Measurements

Those parameters in the APB that are already specified to be operational performance parameters (MOEs, MOSs, or MOPs) from the ORD need not be specified as CTPs unless those operational performance parameters are also contractually specified. Those APB parameters that are not operational performance parameters and are not contractually specified should be specified to be an operational performance parameter if the parameter is most appropriately tested in an operational environment or a CTP if more appropriately tested in a controlled environment. In either case, the specified CTP or operational performance parameter should be annotated to reflect that the source for the parameter is the APB.

Critical Opera Issue

Step seven. Prepare a "what to test" parameter dendritic that shows how all the test parameters are related to each other (Figure 7). This dendritic is useful in checking for consistency among the "what to test" parameters and is useful in test planning in determining what test data elements will be needed. When complete, all MOEs and MOSs must be linked to a COI. If not, specify a COI that addresses the top-level issue that the MOE or MOS addresses. All CTPs should be linked to a MOE, MOS, and in some cases directly to a COI. Note that the dendritic includes both CTPs and operational performance parameters. Those CTPs that are not operational performance parameters should be linked to COIs and MOEs, MOSs, and MOPs. This linkage is important in determining how technical performance affects required capabilities. During operational testing, the OTA has the latitude to treat a CTP that is not duplicated by an operational performance parameter in the same manner that operational performance parameters are treated. The primary differ-

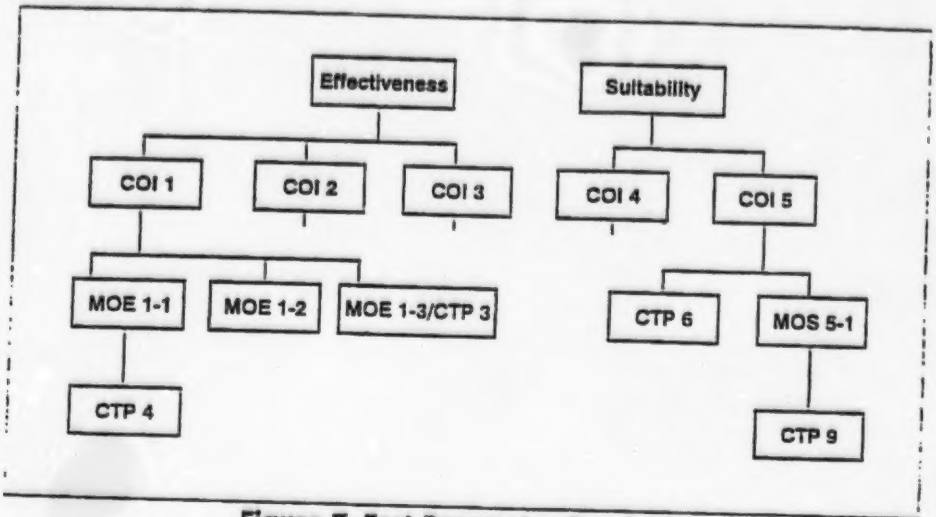


Figure 7. Test Parameter Dendritic

ence is that the environment that was controlled for testing CTPs is now uncontrolled. The OTA is not limited to previously specified thresholds for a CTP. During operational testing, the CTP is simply a criteria to be used in the evaluation and determination of MOEs, MOSs and MOPs.

Step eight. The final step in this process is to ensure that consistency (harmonization and linkage) is established between the "what to test" parameters among the key acquisition documents (TEMP, ORD, APB) and the measures criteria used in the analysis of alternatives.

CONCLUSION

This article has discussed the latest DOD 5000 series guidance on specifying "what to test" parameters, how to establish consistency (harmony and linkage), and has outlined an eight step process to implement this guidance.

This process is complicated by the complex terminology that varies within the various parts of the DoD 5000 series. A key simplification is to limit CTPs to contractually specified performance that is most appropriately tested during developmental testing. The operational performance parameters from the ORD are listed in the TEMP and are more appropriately tested in an operational environment. This type of specification process does not prohibit the test manager from testing some of the operational performance parameters during developmental testing or testing CTPs during testing that is primarily operational in nature. In fact, a wise program manager will ensure that this happens. However, this process does clearly recognize that operational performance parameters are designed for operational testing while critical technical parameters are designed for developmental testing.

Data Requirements

By John O'Keefe

- Body dimensions by body parts
  - Width
  - Height
  - Depth
  - Volume (x,y,z)

- Sensor
  - Aperture
  - Attenuation
  - Performance range/characteristics

- Detector
  - Characteristics
  - Power consumption

- Acclimation

- Chemical attribute
  - Toxicity
    - Threshold level
    - Incapacitation level
    - Lethal level

- Weapons characteristics
  - Error by component
    - Range
    - Deflection
    - Elevation
  - Shots/burst
  - Shots/minute

- Terrain
  - Soil composition
  - Vegetation
  - Roads
  - Paths
  - Elevation
  - Rocks

- Weather
  - Temperature
    - Ambient
    - Radiant
  - Humidity
  - Wind
    - Speed
    - Direction
  - Cloud cover
  - Light conditions

- Clothing
  - Thermal insulation (clo)
  - Moisture permeability
  - Weight
  - Agent attenuation
  - Ballistic retardation

- Field of view

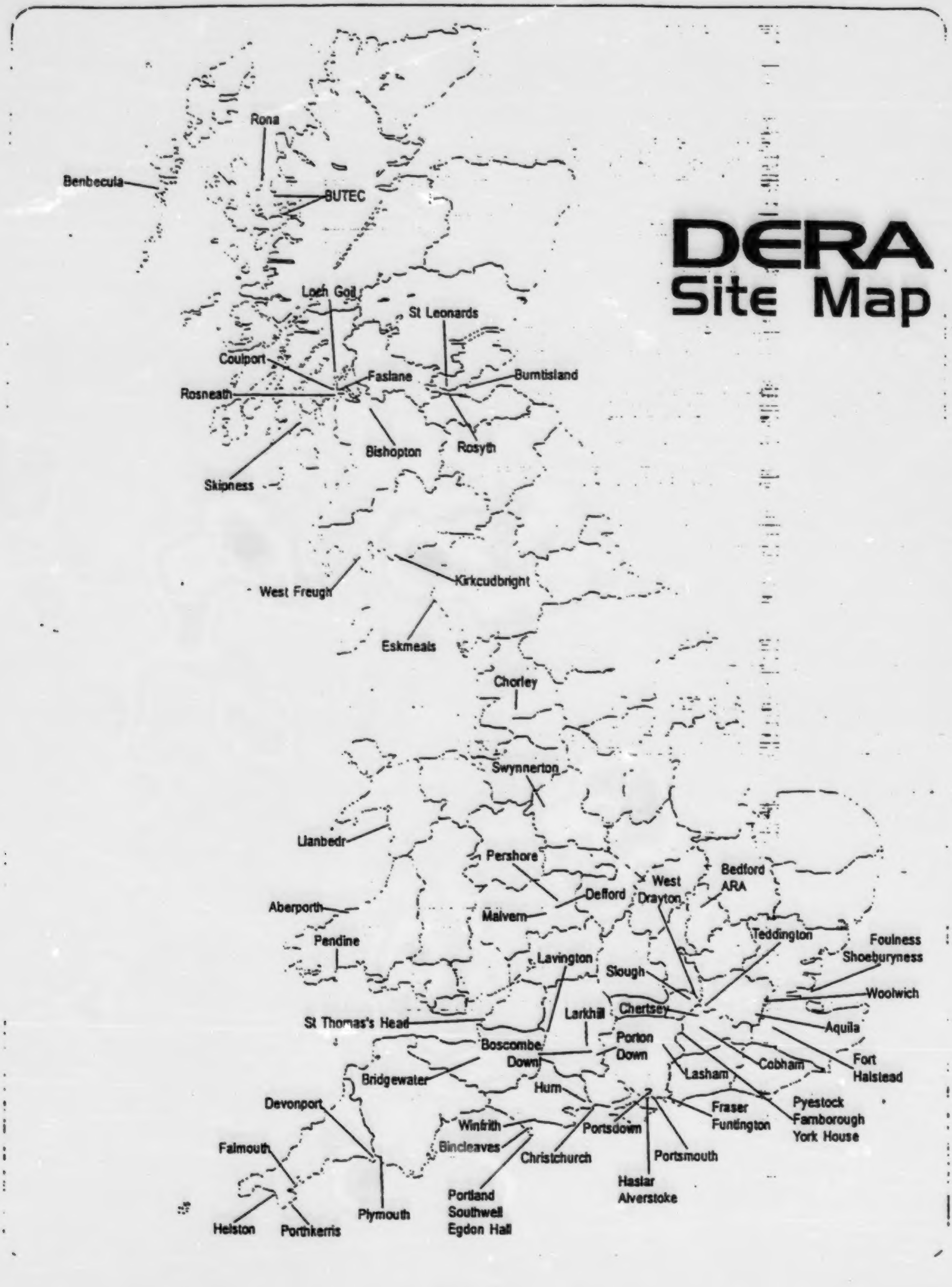
- Maximum/minimum range for each target/viewer posture detection

- Suppression
  - Stimulate and responses

- Acquisition time

- Weapons characteristics
  - Range
  - Speed (muzzle velocity)
  - Caliber
  - Effective range
  - Weight/distribution
  - Acquisition time
- Tasks
  - Individual
  - Unit

DERA Site Map


Rona
Benbecula
BUTEC
Loch Goil
St Leonards
Coulport
Faslane
Burntisland
Rosneath
Bishopton
Rosyth
Skipness
West Freugh
Kirkcudbright
Eskmeals
Chorley
Swynnerton
Llanbedr
Pershore
West Drayton
Bedford ARA
Defford
Aberporth
Malvern
Pendine
Teddington
Foulness
Shoeburyness
Lavington
Slough
Woolwich
Chertsey
St Thomas's Head
Larkhill
Aquila
Porton Down
Boscombe Down
Cobham
Fort Halstead
Bridgewater
Lasham
Hurn
Devonport
Pyestock
Farnborough
York House
Fraser
Funtington
Winfrith
Portsdown
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